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Southwestern Border Water Problems

By J. B. Lippincott

FOLLOWING the Mexican war the Treaty of Guadalupe Hidalgo was signed in 1848. By the terms of the treaty the Rio Grande is made the international boundary line between the United States and Mexico from the Gulf of Mexico to El Paso, a distance of 1,200 miles, and the Gila River from its source to its junction with the Colorado and "... thence across the Rio Colorado, following the division line between Upper and Lower California, to the Pacific Ocean."[1] A map attached to the treaty shows the southern boundary of Upper California, starting at the northern point of Montague Island in the Gulf of California and running to the Pacific Ocean one marine league south of San Diego Bay.

The treaty states: "... in order to preclude all difficulty in tracing upon the ground the limit separating Upper and Lower California, it is agreed that the said limit shall consist of a straight line, drawn from the middle of the Rio Gila, where it unites with the Colorado, to a point on the coast of the Pacific Ocean, distant one marine league due south of the southernmost point of the Port of San Diego." The map which was agreed to, delineated the boundary line between the countries and carried the signatures of the Plenipotentiaries and the seals of each country. It will be

A paper presented at the California Section meeting at Riverside, California, October 28, 1938, by J. B. Lippincott, Cons. Eng., Los Angeles.

[1] Compilation of Treaties in Force, 1904, p. 517.

noted that there is an astonishing divergence between the southern boundary of California as indicated on the official map, and the boundary as indicated by the wording of the treaty, which moves the southeastern corner of California upstream 70 miles and eliminates the Delta of the Colorado from the United States, giving it to Mexico. The boundary monuments were placed in accordance with the wording of the treaty. I have never heard any adequate explanation of this contradiction.

Article VI of this treaty provides that the vessels and citizens of both countries should have free and uninterrupted passage of the Colorado River below the international boundary line.

The Gadsden Treaty which modified the southern boundary of Arizona, was ratified on June 29, 1854. By it the United States purchased the lands south of the Gila River to the present Arizona boundary, which ran to a point on the Colorado River 20 English miles below the mouth of the Gila, thence up the middle of the Rio Colorado to the point of intersection with the line between Upper and Lower California. This makes the Colorado River an international boundary line for some 20 miles below Yuma. Below this point for approximately 80 river miles to the Gulf the old channel of the Colorado River is all in Mexico. Article IV of the Gadsden Treaty states: "The vessels and citizens of the United States shall in all time have free and uninterrupted passage through the Gulf of California to and from their possessions situated north of the boundary line of the two countries." (That is by navigating the river.) The same privileges are granted to the vessels and citizens of both countries for the navigation of the portion of the river that is the international boundary line. As the irrigation developments in recent years have frequently diverted all the waters of the Colorado River, the courts and diplomats have continued to discuss the navigability of the river. It is my understanding that the Colorado River is still officially navigable.[2]

Severe drought prevailed in the Southwest following the year 1890. This, coupled with the extension of irrigation development in the upper reaches of the Rio Grande, produced a shortage of water both in the United States and Mexico in the El Paso area. It led to an international convention with Mexico in 1906 which called for the construction of the Elephant Butte Dam, 120 miles

[2] Compilation of Treaties in Force, 1904, p. 529.

above the City of El Paso (completed in 1916) and an agreement for delivery by the United States of 60,000 acre feet of water annually in the bed of the Rio Grande at the head of a Mexican canal leaving the river at Juarez.[3] This volume of water was sufficient to irrigate all the lands that previously had been locally irrigated by the Mex-

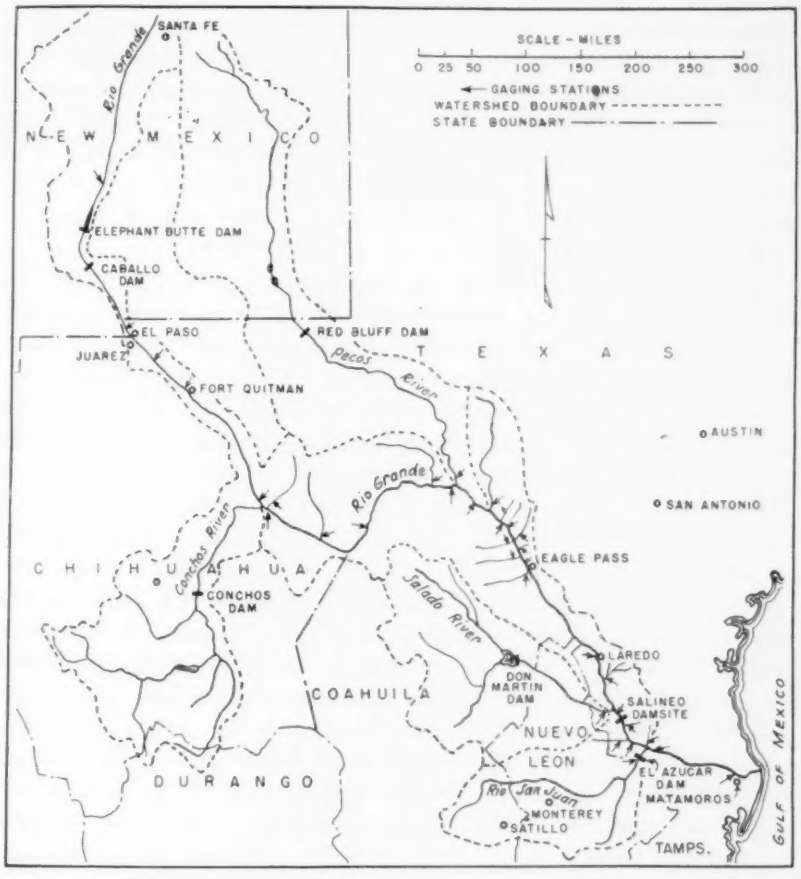

FIG. 1. DRAINAGE BASIN OF THE RIO GRANDE RIVER

icans. In consideration of this the Mexican Government waived all claims to the other waters of the Rio Grande originating above

[3] Report of the American Section of the International Water Commission, United States and Mexico, House Docume..t 359, 71st Congress, 2nd Session, p. 14.

Fort Quitman. The water entering the Rio Grande above El Paso originates in the United States. The Elephant Butte reservoir has such large capacity that no water has passed over its spillway. It serves all the valley lands in the El Paso region.

Until recently the water for the El Paso side of the Juarez-El Paso Valley was taken from the river at the so-called "International Dam" by means of the Franklin Canal, the Mexicans taking their water in the Acequia Madre. A concrete diversion dam has just been completed on the United States side of the line by our Boundary Commission, and water is delivered from it to the Franklin Canal for United States land and a measured supply of 60,000 acre feet is turned down the channel of the river for the Mexican canal. Prior to this arrangement there was no control of the amount taken by the Mexican canal.

The increase in salinity of the waters of the Rio Grande due to their use and re-use in its long drainage basin is of interest. The river rises in high granitic mountains in Colorado where the salinity of the water is low, amounting to 110 p.p.m. (.15 ton per acre foot of water) at Del Norte, Colorado. Tributaries enter along its course. At the Colorado-New Mexican boundary line the salt content has increased to 206 p.p.m. After the water is used near Albuquerque and as it enters the Elephant Butte reservoir, this salinity has increased to 427 p.p.m. At El Paso it has become 832 p.p.m., equal to 1.13 tons per acre foot, and at the lower end of the El Paso Valley at Fort Quitman, it is 2,120 p.p.m. or 2.88 tons per acre foot. This increase in salinity with the irrigation use of water in the upper basin of the Rio Grande is interesting when considered in connection with the prospective greater irrigation use of the Colorado River in its upper drainage basin.

The first United States and Mexican International Water Commission was authorized by Congress on May 13, 1924. It consisted of three members. The Act authorized it to study only the uses of the Rio Grande below Fort Quitman. Mexico stated it would like to have the waters of the Colorado considered at the same time and has consistently maintained this position since.

Complying with the request of the Mexican authorities, the United States Congress on March 3, 1927 passed an additional Act which authorized the Commission to consider the distribution of the waters of all three streams which cross or lie along the international

boundary line between the two countries, namely the Rio Grande, the Colorado and the Tia Juana.[4]

A number of joint sessions of the first Commission were held but no agreements were reached. The United States Commission thereupon recommended to its government the continued collection of hydrographic and other related data and the construction of a large reservoir in the Canyon section of the lower Rio Grande to control the flood flows.

Several large reservoir sites exist on the lower river. About 4,000,000 acre feet per annum of river water wastes into the Gulf.[5] These wise recommendations are still believed to offer a proper solution of the Rio Grande problem.

Second International Water Boundary Commission

A second International Water Boundary Commission was created by an Act of Congress of June 30, 1932.[6] L. M. Lawson, is the sole commissioner for the United States. His headquarters are El Paso. Prior to his appointment as Commissioner, Mr. Lawson was for a number of years engineer for the Yuma Project on the Colorado, from which assignment he was transferred to the Rio Grande Project of the U. S. Reclamation Service. He is thus familiar with both rivers.

This second commission has devoted most of its work to the rectification and control by levees of the Rio Grande below El Paso. Below El Paso and above Fort Quitman, the river meanders for 155 miles through the lower El Paso Valley. Below Fort Quitman it flows through a canyon. The last 100 miles of its course are across its delta. In the past when the river changed its course, by erosion and deposition, the international boundary line followed the thread of the stream, but when the change was by evulsion or violence, the boundary line remained in its original position. Many difficulties arose from such an unstable boundary line. This situation resulted

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[4] Report of the American Section of the International Water Commission, United States and Mexico, 71st Congress, 2nd Session, House Document 359, p. 1.

[5] Ibid., p. 29.

[6] International Boundary Commission, United States & Mexico, Water Bulletin 2, p. 3.

in the Treaty of 1933[7] which provided for the fixing of a permanent channel between the levees through the El Paso-Juarez Valley. The International Boundary Commission by survey made a definite location for the river channel between El Paso and Fort Quitman, eliminating bends and shortening its course to 85 miles. This location is such that it transferred back and forth to the two countries exactly the same amount of land. The United States pays 88 per cent of the construction expense and Mexico 12 per cent. The construction work is nearly completed and is satisfactory to both governments. The expense has been six million dollars, including the Caballo Dam. The negotiating of this treaty based as it was on engineering facts, is peculiarly gratifying. May this method be continued in the future.

There is a remarkable cultural development in Texas from the lower Rio Grande, the irrigable area under existing works below Fort Quitman totaling 582,000 acres in 1932.[8] Of this area 376,000 acres was irrigated largely to citrus fruits and winter vegetables. Here there are many towns with improved streets and beautified homes resembling Southern California. Twenty-five thousand acres was irrigated on the Mexican side of the river in 1932. There is an international flood control project which provides for the raising and strengthening of about 300 miles of river and flood-way levees. Construction in the United States began in December 1933 under Public Works Administration allotments of $2,000,000. The total cost of the project is estimated to be $6,890,000.

Rio Grande Tri-State Compact

The drainage basin of the Rio Grande River is physically divided into that portion above and below Fort Quitman in the State of Texas 85 miles below El Paso. As previously stated, all of the water of the Rio Grande is stopped at the Elephant Butte reservoir and no material amount of new water enters between Elephant Butte and Fort Quitman. The states of Colorado, New Mexico and Texas are all vitally interested in the waters of the upper portion of the Rio Grande and there have been numerous controversies concerning them. To aid in the adoption of a tri-state compact, the Federal

[7] Treaty Series 864, Rectification of the Rio Grande, signed Feb. 1, 1933.

[8] Brief Summary of Lower Rio Grande Data, International Boundary Commission, March 15, 1938, p. 8.

Regional Planning Committee made an investigation of the Upper Rio Grande Basin and has published an interesting report dated February, 1938, of their studies which extended over two years. Transmountain diversions from the headwaters of the Colorado River to those of the Upper Rio Grande were investigated. They find that 554,000 acre feet per annum can be so obtained at an estimated cost of $35,896,000, equal to $65 per acre foot of plant capacity. This proposed transmountain diversion has a bearing on the lower Colorado River projects, which will be mentioned below. A proposed compact is presented by this Committee to the three states.

The average amount of water of the Rio Grande discharged into the Gulf at the Matamoros station for the period 1924 to 1936 was 3,911,395 acre feet.

Below El Paso 34 per cent of the water entering the Rio Grande originates in the territory of the United States, and 66 per cent comes from Mexican tributaries.[9] House Document 359[10] states that 94 per cent of the consumptive use of water diverted from the Rio Grande below El Paso in 1929 occurred in the United States. In 1938 the value of the cultural investments depending upon the waters of the lower river in Texas was $384,000,000. There are 1,264,000 acres of land irrigable from the lower river in Mexico and 1,055,000 acres in Texas.[11] The total area of land irrigable from the tributaries of the lower Rio Grande is 411,000 acres in the United States and 1,178,000 in Mexico.[11]

The El Jardin reservoir site is situated on the main river between Laredo and Eagle Pass, with an available capacity of 3,000,000 acre feet. The Salineno site also on the main stream is near where the Rio Salado joins the river, having a feasible capacity of some 450,000 acre feet. The El Jardin reservoir could be used for the conservation of hold-over storage and the Salineno as a terminal regulating reservoir.

While there is the possibility of large storage on the main stream above the Delta, it is an international boundary line and the consent of both governments is necessary to construct dams. The natural flow of the Rio Grande is erratic, floods being followed by

[9] Int. Water Boundary Com., Brief Summary of Lower Rio Grande Irrig. Data, p. 2.

[10] House Document 359, 71st Congress, 2nd Session, p. 25.

[11] Ibid., p. 26.

periods of drought throughout the year. There is frequently a deficient supply to meet present demands. As stated above, storage of floods on the lower river as proposed by the first International Water Boundary Commission is the best solution of the Rio Grande problem.

Under average conditions the greater volumes of flow of the Rio Grande occur during the months of June and September. Irrigation demand is greatest during March and August and least in July, September and December. The rainfall on the lower Rio Grande varies from 20 inches on the Delta to 8½ inches at El Paso. The duty of water on the Delta is but 1.6 acre feet per acre per annum.

The lands of the lower Rio Grande are largely fertile clay loams. The climate is favorable to the growth of grapefruit. The mouth of the river is in almost the same latitude as the southern extremity of Florida.

Mexican Program for Tributaries of the Lower Rio Grande

Since 1926, the Mexican Government has been building storage and irrigation works on the main tributaries of the lower Rio Grande which enter from the Mexican side. Three projects have been constructed and a fourth is under construction as follows:

Don Martin project on Rio Salado irrigates 165,000 acres; Conchas project on Rio Conchas irrigates 165,000 acres; Rio San Diego project irrigates 40,000 acres; and the Rio San Juan project, begun about Jan. 1, 1937 will irrigate 151,000 acres. These projects will irrigate a total of 521,000 acres.[12]

The Rio San Juan Project proposes the irrigation of about 151,000 acres of land and is one of the largest developments on any of the Mexican tributaries. It involves building the Azucar Dam 20 miles south of Rio Grande City, Texas. This stream has a large watershed and has recently (1938) staged a flood of about 200,000 second feet below Monterey, Mexico.

In 1932 the total area in Mexico irrigated from tributaries below Fort Quitman was 358,000 acres, and recent estimates of future extensions on these tributaries add 598,000 acres[12] to the area irrigated in 1932.

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[12] International Boundary Commission, Brief Summary of Lower Rio Grande Irrigation Data, March 15, 1938.

In spite of the development of projects on the Mexican tributaries there remains necessity for international dams, not of such large reservoir capacity as the first International Water Commission visualized, but of some large regulatory capacity. The unused flow of the Rio Grande at Matamoros in 1937 was 3,772,930 acre feet.

The Colorado River Basin

The Grand Canyon divides the Colorado River into upper and lower areas which radically differ. Above the Grand Canyon a small area near Grand Junction and Mt. Rose is below 5,000 feet in elevation, but the greater portion of the upper area is above 7,000 feet and is relatively cold. This section mostly consists of an undulating sagebrush country, with some forests at higher elevations. Crops consist largely of meadow grasses in the river bottoms. In a drive of approximately 1,500 miles through this upper drainage basin in 1938 the writer saw few localities offering opportunities for large irrigation expansion. A number of projects, which will be referred to below, have been proposed for transmountain diversions from the Upper Basin.

The irrigable lands below the Grand Canyon exclusive of the Gila, are mostly below 500 feet in elevation. This area is hot and capable of growing winter vegetables and semi-tropic fruits. There are large flat plains in the United States and Mexico, on which water can be efficiently distributed. It is proposed to export 1,000,000 acre feet of water a year from the lower river for domestic uses on the coastal area of Southern California. The Gila River has a net average annual water crop of about 1,300,000 acre feet. The total drainage area of the Colorado above Yuma, including the Gila, is 244,800 square miles.

The southern boundary of California is 70 miles from the Gulf of California. Due to continual deposition of silt, the bed of the river across the Delta is higher than the general level of the country opposite. In 1904 the river flowed along the easterly side of the delta to the sea. When the river broke through into the Salton Sink in 1905[13] its former channel grew up with brush so that what now remains of the stream, south of the boundary, flows first in a southwesterly direction towards "Volcano Lake" (which has now been

[13] Engineering News, Feb. 22, 1906, p. 217.

FIG. 2. COLORADO RIVER BASIN, WITH PRINCIPAL RESERVOIR SITES (from *Civil Engineering*, May 1935)

filled with silt) and thence largely by the Hardy Colorado to the Gulf of California.

There are no tributaries contributing to the Colorado River below the international boundary. The melting of snow in the high mountains of Colorado, Utah and New Mexico produces the maximum stages of river flow during the months of May and June, with low water in August and September. Occasional floods occur in the lower basin due to summer storms. Before the building of the Hoover Dam, the Imperial Valley and the delta of the river in Mexico were menaced by floods. Because the Salton Sink of the Imperial Valley is 250 feet below sea level there was a constant danger of the river flowing into it, as the gradients thereto below the international boundary are 3.5 times steeper than they are to the Gulf of California. Flood flows to the Salton Sea are prevented by the construction of levees in Mexico by Americans. The building of the Hoover and Parker dams on the Colorado, as well as reservoirs on the Gila, greatly reduce the flood menace on the lower river.

Because of the higher crop values and the greater facility for the distribution of large quantities of irrigation water, beneficial uses of the portion of the stream below the Grand Canyon are more extensive than in the upper basin. When the building of Hoover Dam was proposed, the upper basin States at first opposed the project, because its construction would create an extensive priority of beneficial use of the water below the Grand Canyon, as against areas above. To overcome this opposition, Herbert Hoover, then Secretary of Commerce, called the "Sante Fe Conference" between the 7 basin states.

This resulted in the Colorado River Compact in 1922. It provides that, in each ten-year period, the Upper Basin States shall turn down 75,000,000 acre feet of water for the Lower Basin States which is about one half of the run-off. It also provides that if an agreement is reached for the delivery of water to Mexican lands, such delivery should be made from surplus water after the projects in the United States are served, but if this surplus water is inadequate, then both Upper and Lower Basin States should equally contribute to overcome the Mexican deficiency. Any amount that the Lower Basin States have to contribute to Mexico must be supplied equally from the Arizona and California allotments. The Colorado River Compact was ratified by Congress and by the states involved except Arizona.

Numerous Purposes of the Hoover Dam

Following the Colorado River Compact the Hoover Dam was built to a capacity of 30,500,000 acre feet for the regulation of the floods of the Colorado, improvement of navigation, conservation of water for irrigation, other beneficial uses exclusively within the United States, and for the generation of power.[14] At the present time there is an installation capable of developing 450,000 kilowatts. The return of the entire cost of the dam to the government for principal and interest at 4 per cent is secured by firm contracts, a condition which in these days is unique.

In 1922 the annual transmountain diversions in Utah and Colorado were 127,000 acre feet, said to be capable of enlargement to 444,000 acre feet.[15]

In the report of the Regional Planning Committee for Upper Rio Grande, February, 1938, a transmountain diversion from the San Juan tributary of the Colorado to the upper Rio Grande basin of 554,000 acre feet per annum is described at an estimated cost of $36,000,000, or at the rate of $65 per acre foot of capacity. This water would be used as a supplemental supply for lands now irrigated but having insufficient water.

The Big Thompson Project, for diversion of some of the headwaters of the Colorado to the eastern slope of the Rocky Mountains near Estes Park, was approved by the President, December 28, 1937. This involves construction of a 13-mile tunnel and an expenditure of $44,000,000. The safe supply available therefrom is given as 300,000 acre feet per annum. Secretary Ickes executed a contract with the Northern Colorado Water Conservancy District for this construction on July 27, 1938.

It is understood that the Denver municipal water works is now diverting water through a pilot tunnel of the Moffat Railroad Tunnel. Certain charts which have been furnished to the writer show that the waters of Frazer, Vasquez, St. Louis and Ranch creeks can be diverted through this tunnel. It is computed that for an average of 24 years and with a tunnel capacity of 600 second feet that 81,300 acre feet per annum can be so obtained for the domestic water supply

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[14] Hoover Dam Contracts, p. 407.

[15] Problems of the Imperial Valley and Vicinity, p. 173, published by Government Printing Office, 1922.

of the City of Denver. The capacity of the diversion tunnel can be increased from 600 to 1200 second feet.

Projects for transmountain diversions which a few years ago would have seemed fantastic because of the expense, now are being adopted by the Government. It is stated by officials who can best judge that the aggregate of these diversions will be 2,250,000 acre feet per annum. This has a very direct bearing on both the quality and volume of the available water supply for the lower Colorado River basin.

All these governmental transmountain diversions should be retained under Federal control to provide for the compliance with the Colorado River Compact for turning down to the Lower Basin States their allotment of 75,000,000 acre feet each 10 years. No court order could be enforced against the multitude of private ditches in the upper basin.

Diversion Threatens to Increase Salinity

While analyses of the water at the proposed diversion points are not available, they are all at high elevations, near the crest of the mountains, where the quality of the water is excellent, as compared to that entering Boulder reservoir. If, therefore, 2,250,000 acre feet of this high quality water is taken away, the salt content of the remaining water at Boulder, will be increased. Also the seepage and return water from the irrigation of the lands in the Upper Basin will have the same effect. A thorough study of this subject should be made, based on the present plans.

"A calculated weighted average for the 10 years ending September 30, 1935, indicates that the content of dissolved salts in a uniform mixture of all the water that passed the Grand Canyon station during that period, with no allowance for change in composition due to evaporation, would have been 582 parts per million or 0.79 ton per acre foot."[16]

The quality of Colorado River water entering Lake Mead varies greatly with the volume of annual discharge. In the year 1929 with an annual flow of 19,400,000 acre feet the weighted dissolved solids were 555 p.p.m., whereas in 1934 with the extreme low flow of 4,674,000 acre feet they amounted to 960 p.p.m. Analyses of the

[16] Letter from Metropolitan Water District to Dr. L. D. Bachelor in 1936.

water in Lake Mead show that the mixing is not complete. The flood flows of May and June of the Colorado River come largely from the melting of snows in the high mountain regions of the basin. These waters naturally are of much greater purity than the low water flows which are derived from springs and seepage.

For parts of the time since the closing of the gates at Hoover Dam the water in the river below the dam has carried less dissolved mineral salts than water which would have been available if there were no dam. At other times it carried more. For instance in the low flow in January and February of 1936, the water at Willow Beach below the dam contained 486 p.p.m. of dissolved mineral salts, whereas above the reservoir at Grand Canyon station it carried 1,162. In the high water flows from April 21 to June 30, 1936 there were 606 p.p.m. at Willow Beach below the dam and 310 p.p.m. in the river entering the reservoir.

Dissolved Mineral Salts Vary by Depths

The increase, on certain occasions, in the quantity of soluble mineral matter in the water discharged from the reservoir as compared to that entering the reservoir, is said to be the result of inadequate mixing rather than of solution of any deposits of salt in the reservoir. It is stated that an examination of samples collected at different depths in Lake Mead has shown a stratum of about 50 feet of water containing a much smaller quantity of dissolved mineral salts than the main body of the lake. The impounded water in Lake Mead has covered some old salt mines but examination of top and bottom samples of water from the lake near the mouth of Virgin River did not show any increase in chloride that could be attributed to dissolution of these salt beds. The analyses that have been made during the past year suggest that there may always be layers of water of different composition at different depths in Lake Mead and that the composition of the water released may depend in part on the elevation at which it enters the outlet towers and in part on conditions which at this time cannot be predicted with any confidence.

The above data is largely based on Department of the Interior memoranda for the press, Analyses of Colorado River water, July 25, 1935, Nov. 20, 1937, May 18, 1937 and a letter from the Director of the U. S. Geological Survey to the writer, March 19, 1938. The

river water at Yuma in June, 1938[17] contained 830 p.p.m. of dissolved solids, in August 723 p.p.m. and in September 713 p.p.m.

Metcalf and Eddy, engineers, reported on the softening of the Colorado River water to be supplied to member cities of the Metropolitan Water District under date of March 21, 1936. On page 14 they state that the corresponding long-time average dissolved mineral salts in the water to be taken from the Parker reservoir, after due allowance for evaporation losses, will be approximately 600 p.p.m. This is equivalent to 0.8 ton of mineral matter per acre foot. They also state (page 15) that giving consideration to all factors of evaporation, the long-time average hardness of the water that will be obtained from the Parker reservoir will be 300 p.p.m. This is said to be comparable to an estimated average total hardness of the waters of the member cities of the Metropolitan Water District of approximately 180 p.p.m.[18]

The softening of Colorado River water for domestic use is recommended by Metcalf and Eddy. A factor to be considered in connection with the softening of water by the lime and soda ash process proposed is that the reducing of the hardness caused by lime and magnesium will result in an increase in the amount of sodium in the water, which will be less favorable for irrigation.

Sodium Contents Not Detrimental in Irrigation

The writer was familiar with conditions on the lower Colorado River 35 years ago when irrigation was in its infancy on the lands of this region. On two occasions recently he has re-examined these irrigated areas in order to observe the long-time effect of using the raw Colorado River water on them. These observations indicated that on lands where either natural or artificial drainage was effective, this raw water has been used successfully for agriculture including citriculture. Drainage is essential.

The answer to any objection to the quality of the Colorado River water is that it was the only additional supply available for Southern California. Southern California is over developed and would have to retrograde without more water.

The Proceedings of the American Society of Civil Engineers of

[17] Letter from Rubidoux Laboratory of Dept. of Agriculture, Sept. 3, 1938.
[18] Report of Metcalf & Eddy, p. 4.

April, 1937, contains an interesting paper by Nathan C. Grover and Charles Howard entitled "The Passage of Turbid Water through Lake Mead." Those desiring detailed information relative thereto are referred to it. In this paper it is stated turbid water was discharged from Lake Mead three times during the 11 months from February 1, 1935, when storage began, to December 31, 1935. During these months less than 10,000 second feet was flowing through the tunnels at the base of the dam. When the turbid discharge occurred, the lake was from 70 to 90 miles long and contained from 4,000,000 to 5,000,000 acre feet of water. The authors state that the changes in the quantity of suspended matter below the reservoir apparently resulted from an increase in river discharge and suspended matter at the Grand Canyon station a few days previous. Apparently the water flowing into the reservoir at these times not only contained large quantities of suspended matter, but also was higher in chemical contents than the body of the water in the reservoir. This water having greater specific gravity therefore flowed through the body of the reservoir without complete mixing.

Surplus Water for Mexico

So many uncertain factors enter a computation of the amount of surplus Colorado River water that will ultimately pass into Mexico under the allocations for the various projects, that the answer obtained is speculative and uncertain. Several estimates have been made by authorities who state that the computation must not be considered exact.

E. B. Debler of the Bureau of Reclamation, in December, 1934, wrote a report entitled "Stream Flow of the Lower Colorado River and Its Tributaries." He presents, on page A, the information given in table 1, in which the Gila River supply is not included. In this tabulation it is estimated that the Upper Basin States will use or divert out of the drainage basin 7,500,000 acre feet per year. The net *ultimate* supply for use below the Hoover Dam, after deducting reservoir and stream channel losses and for waste past Laguna Dam for silt sluicing, is given in the Debler estimate as 8,370,000 acre feet. This shows an apparent surplus of 870,000 acre feet. Deliveries to Mexico are not included in this table.

Engineers who are qualified to express an opinion on the ultimate amount of water that will be used or diverted by the Upper Basin States believe it to be less than the 7,500,000 acre feet allocated to

the Upper Basin under the Colorado River Compact. The best information that is obtainable to the writer places it at 6,220,000 acre feet. In addition in the above estimate it is stated that the depletion between Lees Ferry and the Hoover Dam will be 340,000 acre feet. This is understood to be water that may be used in the basin of the Little Colorado River. This basin is in the high plateau region of Arizona. It joins the main river between Lees Ferry and Lake Mead. It is contended that the use of this water should be charged to the Lower Basin, in part to New Mexico but chiefly to the State of Arizona, and should not be deducted in a determination of the water available for uses in California and Nevada. If these two modifications are made it appears to the writer that there would be available for use from the Lower River 9,990,000 acre feet, or 1,620,000 acre feet more than is shown by Mr. Debler as the net supply for use below the Hoover Dam.

Article 3a of the Colorado River Compact apportions 7,500,000 acre feet of water to the Upper Basin and also the same amount to the Lower Basin. Article 3b of this Compact states: "In addition to the apportionment in paragraph (a) the Lower Basin is hereby given the right to increase its beneficial consumptive use of such water by 1,000,000 acre feet per annum." This additional 1,000,000 acre feet per annum apparently is an additional grant of 1,000,000 acre feet to the Lower Basin States. Apparently it is a separate grant from the surplus referred to in other portions of the Compact.

There is a lack of agreement as to whether the waters of the Gila River, estimated at 1,331,000 acre feet per annum, should be considered as a portion of the allocation to the State of Arizona under the Colorado River Compact, Arizona claiming that they should not be so included but the Upper Basin States stating that they should be included. It appears to the writer that there will be a substantially greater amount of water available for distribution on the Lower River than is indicated in table 1.

J. C. Stevens, a consulting engineer of the Bureau of Reclamation, in 1936 presented certain estimates of the flow of the Colorado River as tentative and based on what he terms incomplete data. He finds less surplus water than Debler. A later and more elaborate computation has been made for the Department of State by Joseph Jacobs and J. C. Stevens, consulting engineers, representing the Bureau of Reclamation. This estimate is not available to the writer.

The above estimates are for the *ultimate surplus*, under full development in the Colorado River Basin. They do not represent present conditions. Presumably it will be a generation or more before this ultimate development in the United States occurs. During the intervening period there will be more water passing the Hoover Dam than required for down stream diversions. Both of these conditions will result in large flows passing the international border and hence becoming temporarily available for irrigation uses in Mexico.

TABLE 1

Stream Flow of Lower Colorado River and Its Tributaries

	VIRGIN CONDITIONS, PRIOR TO ALL DEVELOPMENT	FUTURE CONDITIONS WITH FULL DEVELOPMENT*
	acre feet per year	
Depletion above Lees Ferry	0	7,500,000
Flow at Lees Ferry	16,660,000	9,160,000
Inflow, Lees Ferry to Hoover Dam	1,060,000	1,060,000
Depletion, Lees Ferry to Hoover Dam	0	340,000
Flow reaching Hoover Canyon Reservoir	17,720,000	9,880,000
Reservoir loss Hoover Canyon Reservoir	0	520,000
Flow past Hoover Dam	17,720,000	9,360,000
Net river losses Hoover Dam to Laguna Dam	880,000	500,000
Reservoir losses at Bullshead, Parker and Imperial dams	0	90,000
Waste past Laguna Dam for silt sluicing, floods and unusable return flow		400,000
Net supply for use below Hoover Dam		8,370,000
Flow at Laguna Dam	16.840,000	

* Assuming Upper Basin uses 7,500,000 acre feet annually.

Division of Colorado River Water

Under the terms of Articles III A, B and C of the Colorado River Compact, the waters of the Colorado River are allocated as follows:

1. Equal amounts to the Upper Basin and Lower Basin States fixed tentatively at 7,500,000 acre feet per annum, if available in the river and not required for Mexico under some treaty agreement.
2. An additional 1,000,000 acre feet for the Lower Basin if available after supplying 7,500,000 acre feet each to the Upper and Lower Basin States, and if not needed for Mexican allocation.
3. Mexican waters fixed by possible international agreement.

The following is the suggested division of the water of the Lower Basin States in acre feet per annum, under the Boulder Canyon Act, Section 4a:

(a) Nevada	300,000 acre feet
(b) Arizona	2,800,000 acre feet + ½ of surplus under "Compact"
(c) California	4,400,000 acre feet + ½ of surplus under "Compact"
Total of first three	7,500,000 acre feet

The division of the California water according to the All-American Canal contract with the United States (Article 17, Sec. 1 to 7 incl. p. 333) in terms of acre feet per annum is:

1st priority, Palo Verde I. D. water necessary for 104,000 acres
2nd priority, Yuma Project (in Calif.) water necessary for 25,000 acres
3rd priority, (a) Imperial I. D. including Coachella and All-American Canal
(b) Lower Palo Verde mesa, say 16,000 acres

The totals of the allocations for these last named numbers, 1, 2 and 3 as given above, must not exceed 3,850,000 acre feet per annum. This is referred to as an allocation of 3,850,000 acre feet for the agricultural group.[19]

The fourth priority is for the Metropolitan Water District, 550,000 acre feet. The sum of the four above priorities amounts to 4,400,000 acre feet which is the amount of water allocated to California interests (as stated in the All-American Canal contract with the United States) and agreed to by the different parties at interest and recommended to the Secretary by Mr. Hyatt, State Engineer of California, with the approval of the State Division of Water Resources.

The remaining priorities apparently are intended to be supplied from the part interest that the State of California has in the 1,000,000 acre feet of additional water noted in paragraph III-b of the Colorado River compact and in any surplus waters that may be available.

The fifth priority is:

(a) Metropolitan Water District	550,000 acre feet
(b) San Diego	112,000 acre feet

These last two are equal in priority. It is provided finally: "All

[19] Hoover Dam Contracts, p. 32.

remaining water available for use within California, for agricultural use in the Colorado River Basin in California" is allotted to "the agricultural group."

Article 3-F of the Colorado River Compact provides for a further apportionment from time to time after October 1, 1963 of any water unappropriated by paragraphs A, B and C, which paragraphs relate to the states of Nevada, Arizona and California.[20]

What is known as the Gila Project has been adopted by the Bureau of Reclamation. It is proposed that the total area of this project will be in the neighborhood of 500,000 acres. The first unit of 150,000 acres is now under construction. The project is located largely on the porous lands of the Yuma Mesa. Presumably the available allocation of water for Arizona will be used on this mesa. The seepage and return water therefrom should be large.

It will also be noted that Mr. Debler in his table estimates that 400,000 acre feet of water will be wasted past the Laguna Dam for silt sluicing, floods and unusable return flow. Possibly these items would aggregate in the neighborhood of 1,000,000 acre feet of water per annum which could be available for use on Mexican lands. In addition there will probably be large areas of land on the upper and lower river projects for which water has been allocated that will be forced out of irrigation use by the development of high alkalinity in the soils. When all these factors are taken into consideration it appears to the writer that the water supply from the lower Colorado River will be adequate to meet all of the demands that are now contemplated for the Lower Basin States.

As stated, the amount of future surplus water above the requirements of feasible projects within the United States above and below the canyon is highly problematical. The contract of April 24, 1930 between the Secretary of the Interior and the Metropolitan Water District provides for the same order of priority of California rights to the lower Colorado River as given above.[21] The remaining allocation for the Metropolitan Water District and for San Diego must come out of the 1,000,000 acre feet of additional water assigned under paragraph III-b, of the Colorado River Compact and from surplus water.

As previously noted, the statements as to the adequacy of the

[20] Hoover Dam Contracts, p. 6.

[21] Hoover Dam Contracts, p. 68.

supply relate to the ultimate development of the entire drainage basin of the river, which will not occur for one or two generations. The Federal Government, in sponsoring the large transmountain diversions previously referred to, should keep in mind the contracts that have been entered into, for the supply of water for the Lower Basin States.[22] Such diversions affect both the quantity and quality of the water available for the Lower Basin States.

First International Water Commission

The first International Water Boundary Commission between the United States and Mexico (authorized by an Act of Congress approved May 13, 1924) at a session held in the City of Mexico in August 1929, proposed as an equitable division of the waters of the Colorado, to deliver to Mexico the greatest amount which it had diverted to irrigators in that country from the stream in any one year. That year was 1928, during which time Mexican farmers received 750,000 acre feet. The continuity of delivery of this water by the United States was conditioned on the construction by the United States of the Hoover Dam.

At this session the Mexican section presented its claim for 4,500,000 acre feet of water from the river, basing this on the fact that there were in Mexico, tributary to the Colorado River, 1,500,000 acres of irrigable land for which a duty of 3 acre feet per acre per year was regarded as necessary. The Mexican commissioners claimed to have a right to 3,600,000 acre feet under the right-of-way concession that was made by the Mexicans to the California Development Company. No agreement was reached by this first International Water Commission.[23] The area irrigated in the Mexican Delta in 1938, is reliably estimated at 225,000 acres.

Early Irrigation Projects of the Lower River

The earliest irrigation project on the lower river was at Blythe, for the irrigation of the Palo Verde Valley. A rocky point affords a favorable natural diversion. The valley is protected with levees.

A few small canals were built for the irrigation of the Yuma Valley in early years. The construction of the Yuma Project was

[22] Hoover Dam Contracts, p. 407.

[23] House Document 359, pp. 5 and 7.

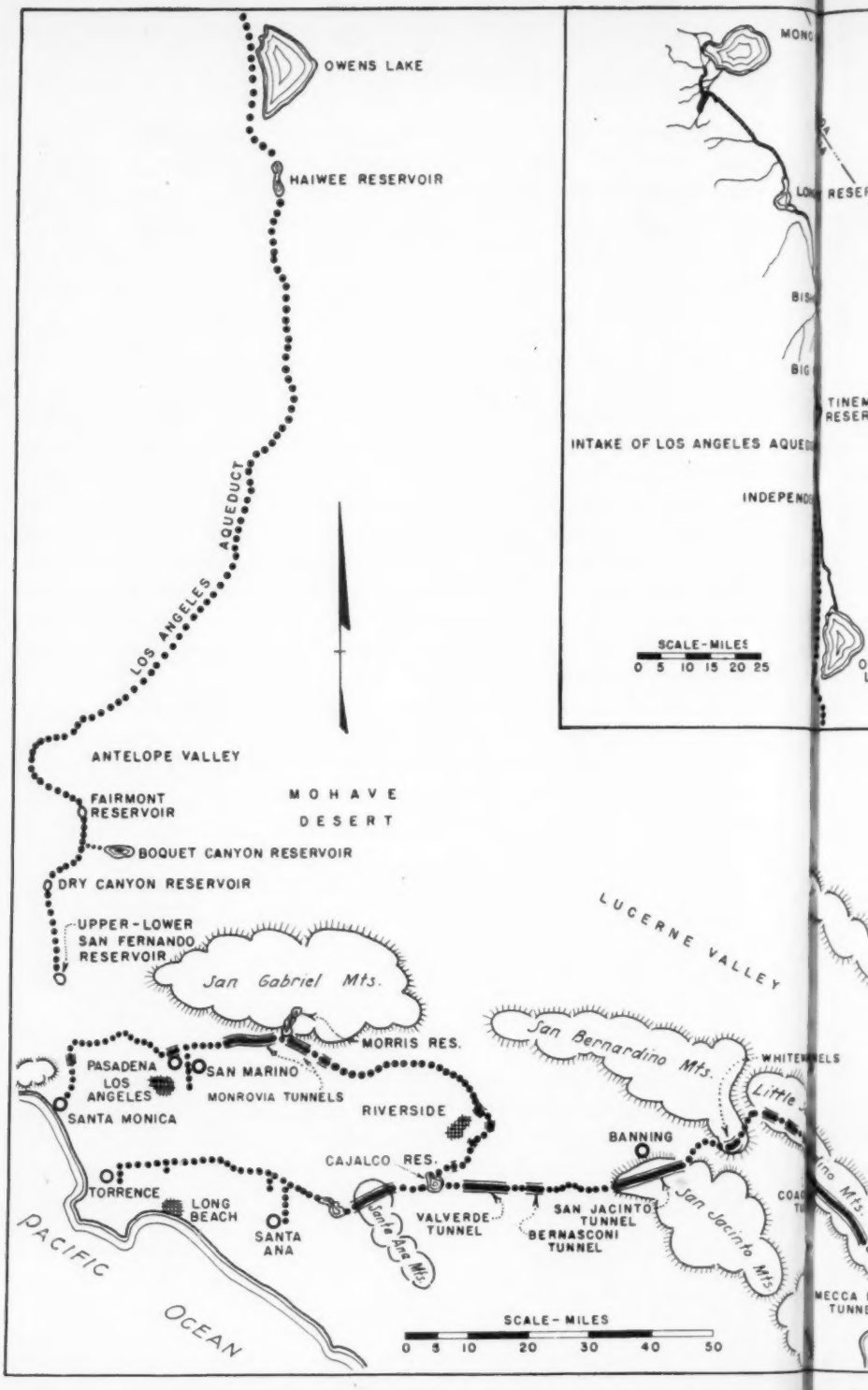
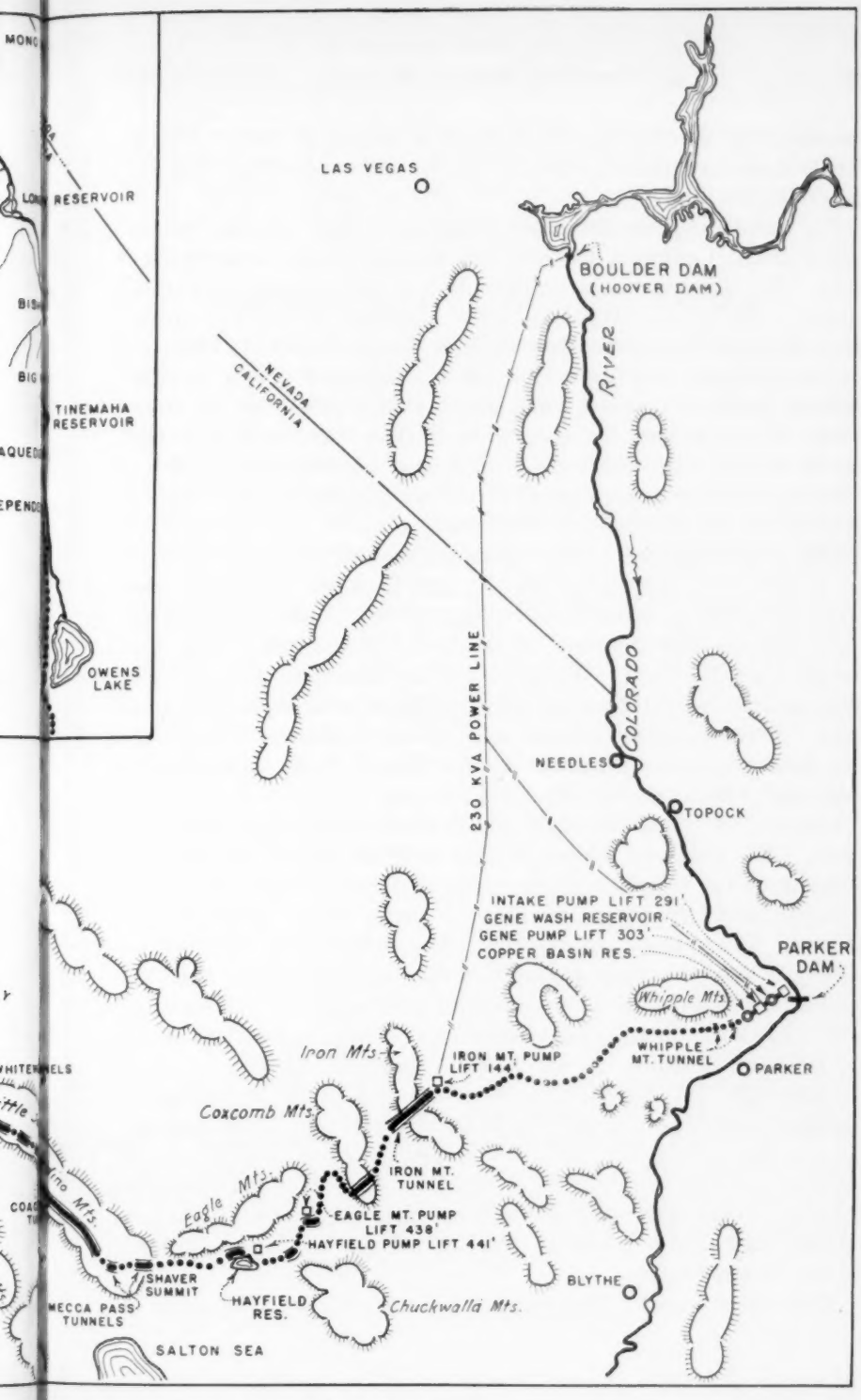


FIG. 3. COLORADO RIVER AQUEDUCT, AND LOS AN



Los Angeles Intake from Mono Lake

authorized by the Secretary of the Interior on May 10, 1904. About 71,000 acres are served. (See J. B. L. Colorado River Report, page 170.)

The Colorado River Irrigation Company, which was the predecessor of the California Development Company, was organized in 1893. The latter company was acquired by the Imperial Irrigation District. A Notice of Appropriation of 10,000 second feet was posted April 25, 1899. Water is diverted from the river, 300 feet north of the international boundary line. It is discharged into a natural drainage line known as the Alamo River, 3 miles below the line, from which it is subsequently diverted in greater part back into the United States. The water diverted is first delivered to a Mexican company, under an agreement for it to furnish water for the irrigation of lands in both Mexico and California.

The Army Engineers, under whose jurisdiction navigable streams are placed by Congress, on July 7, 1903 declined to sanction the diversion works as constructed but agreed not to object as long as the California Development Company did not interfere with the navigation of the river. We here have the interesting theory of the water being diverted for irrigation, but the stream remaining navigable. No documentary evidence is known to the writer by which this corporation was permitted by the United States authority to carry water thus through Mexican territory.

The Gulf of California originally extended to the north as far as Indio. The northern portion of this gulf was cut off by the silt deposits of the Colorado River discharged into it near the international boundary line. The result is that a large portion of the Imperial Valley is an old sea bed. The delta of the Colorado is largely in Mexico. There is said to be 800,000 acres of good irrigable land in the delta south of the boundary. The menace of floods is now removed. There is no existing international agreement as to the rights of Mexico to the waters of the Colorado River.

Under the old contract between the California Development Company and Mexican land owners for rights-of-way for the passage of water to the Imperial Valley, the company agreed to a delivery of water up to half the amount diverted by it to Mexican lands on demand. This agreement was subsequently confirmed by an Act of Mexican Congress, June 15, 1904, but it has not been approved by the United States.

There have been no large diversions of Colorado River water to

Arizona except for the Yuma Project. However, at the present time what is known as the Gila Project, to be served from the Colorado River, has been adopted. Its preliminary unit of 150,000 acres is being constructed for an estimated total cost of $19,480,000. The entire project is said to include over 500,000 acres.

Irrigated and Irrigable Lands in Lower California

In 1926–27 the Bureau of Reclamation made an investigation of irrigated and irrigable lands along the lower Colorado River. Referring to ownership south of the international boundary line in Lower California it is stated[24] that the larger part of the irrigable land in the delta south of the international boundary line was then owned by the Colorado River Land Company, totaling approximately 800,000 acres. Of this area approximately 132,000 acres was classed by the company as mountain and desert, leaving about 668,000 acres of arable land.

A subsidiary of the Southern Pacific Company in 1927 owned a tract of 100,000 acres just south of the international boundary line and west of the river. It is stated in a report of the Colorado River Commission of Arizona, dated June 1938, page 7, that during the past two years all of the land of the Colorado Land Company had been appropriated by the Mexican Government. House document 359 above referred to, page 166, gives an estimate of the areas irrigated from the Colorado River in Mexico from 1905 to 1927, a portion of which is as follows:

1905	3,591 acres
1910	14,920 acres
1915	41,000 acres
1920	190,000 acres
1925	216,000 acres
1927	156,168 acres

These figures were furnished to the International Boundary Commission by the Imperial Irrigation District. Other statements are given in this report which generally show smaller areas irrigated.

The by-passes of the Hoover Dam were closed on May 1, 1936. This largely removed the flood menace from the Imperial Valley and the delta lands in Mexico, since which time the Mexican Government has colonized some of these lands.

[24] House Document 359, 71st Congress, 2nd Session, p. 161.

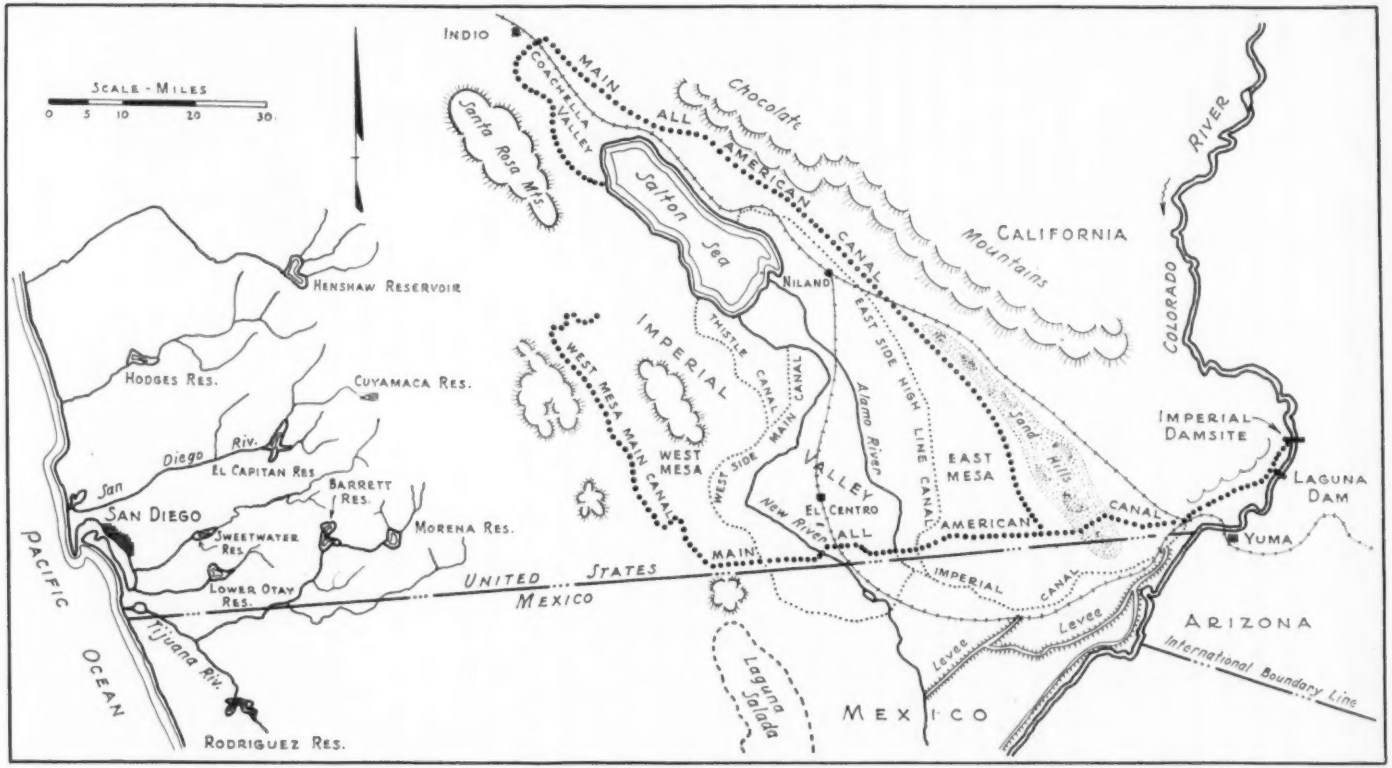


FIG. 4. IMPERIAL VALLEY PROJECTS, SAN DIEGO SUPPLY AND TIAJUANA RIVER

The first International Boundary Commission made the following recommendation in March, 1930: "The interests of both countries will be served by an early agreement as to the extent to which existing uses of water on both the Rio Grande and the Colorado on both sides of the international boundary are to be recognized, but in the absence of such agreement, it is believed that the United States should give notice to Mexico that no rights to water in the Colorado based on future development and extension of existing uses will be recognized until an agreement covering all three streams has been reached.[25]

The Colorado River Commission of Arizona issued a pamphlet in June, 1938 entitled "The Colorado River—International Problem" from which the following quotations are taken (page 4): "that the estimated reclaimable land totals 1,333,400 acres (in Mexico). Approximately 424,000 acres are now under cultivation or are being put under cultivation." Possibly there are 424,000 acres of land under canals in Mexico, but it is improbable that there is so large an area under cultivation. The Arizona Commission states that they have made an investigation recently of the situation in the Mexican delta and they find that there are 5,000 agrarians organized into 50 collectives and that through them the Banco National de Credito Ejidal, F. A., is financing the farming of some 405,000 acres. It is claimed that there are now 35,000 people living in Lower California. "The Mexican Agrarian law is said to provide that 15 or more Mexican citizens may organize a collective group and that this group may make application for a tract of land for its use as a community. . . . The Act of Dec. 2, 1935 . . . established the Banco National de Credito Ejidal, F. A., which was founded for the purpose of giving Mexican citizens of the poorer class financial aid and guidance in the development of farming land in the Republic of Mexico. . . . This bank was established with a capital of 120,000,000 pesos. . . . This bank, besides providing the Ejidatories with farm implements, seed, water and other necessities to conduct general farming operations, has also general supervision of the farming and controls the crops produced, paying each male Ejidatario two pesos per day for sustenance of himself and family."[26] The writer has no personal knowledge of the accuracy of these statements.

In a publication of the Gila Project Association concerning the irrigation of the Yuma Mesa lands, it is stated that the Colorado

[25] House Document 359, 71st Congress, 2nd Session, p. 23.

[26] Colorado River—International Problem, p. 8.

River Land Company has recently made application to the Mexican government for a permit to construct a weir dam across the Colorado River at a point opposite Pescadero, Mexico, seven miles south of the international boundary line.

The Imperial Valley in California

The Imperial diversion dam and the All-American Canal are both a portion of the Hoover Dam Project. The dam now completed is 15 miles above Yuma. From the dam to the Yuma Project this canal has a capacity of 15,000 cubic feet per second; below the Yuma Project to Pilot Knob, 13,000 cubic feet per second; and from Pilot Knob to the Imperial Valley, 10,000 cubic feet per second. The canal is located entirely within the United States. The Imperial Canal now serves over 500,000 acres. In connection with the Hoover Dam this system will ultimately furnish water for over 1,000,000 acres in the Imperial and Coachella valleys.

The Rio Grande and the Colorado are the two greatest rivers in the southwestern portion of the United States. In portions of their course both are international boundaries. No agreement for the division of the waters of these two streams has been entered into. There are approximately 225,000 acres now said to be irrigated in Mexico from the Colorado River which may have their water rights jeopardized by further diversions in the United States. In a similar way there are some 582,000 acres of land under canal in Texas below Fort Quitman which may be jeopardized by diversion from Mexican tributaries of the Rio Grande. The Mexicans insist on the consideration of both the Rio Grande and Colorado at the same time. The Texans are willing to negotiate for the Rio Grande separately.

Manifestly it is to the interest of both countries that some understanding and treaty agreements should be promptly entered into for the apportionment of these waters. In both instances the interests of these countries may be seriously impaired if developments continue therein which would be restricted by ultimate treaty provisions.

Colorado Aqueduct Distribution System

By Julian Hinds

ON SEPTEMBR 29, 1931, the voters in a group of Southern California cities endorsed a bond issue of $220,000,000 to finance the construction of an aqueduct to bring to their borders a supply of water from the Colorado River. Final plans and financial arrangements were completed and actual construction work was started in December, 1932. Construction is now well advanced and completion early in 1939 is assured.

The Metropolitan Water District of Southern California consists at the present time of the cities of Anaheim, Beverly Hills, Burbank, Compton, Fullerton, Glendale, Long Beach, Los Angeles, Pasadena, San Marino, Santa Ana, Santa Monica, and Torrance. The District is governed by a Board of Directors, made up of representatives from these cities. W. P. Whitsett is Chairman of the Board. All engineering and construction work is under the direction of F. E. Weymouth, general manager and chief engineer; and R. B. Diemer, distribution engineer, is in charge of all work on the distribution system.

Water for supplying the aqueduct is derived from floods conserved in Lake Mead, above Hoover (Boulder) Dam. The required flow is released into the river below Hoover Dam and rediverted at Parker Dam, 155 miles downstream. A main aqueduct 242 miles long carries the flow from the point of diversion to the Cajalco Reservoir, about 10 miles southwest of Riverside. The main aqueduct has a peak capacity of 1,605 cubic feet per second or, allowing for shutdowns for repairs, an average capacity of 1,500 c.f.s. Because of high ground to be crossed, and for other reasons, this flow must be lifted 1,617 feet. Five pumping plants are required, with lifts

A paper presented at the California Section meeting at Riverside, Calif., October 28, 1938, by Julian Hinds, Asst. Ch. Eng., Metropolitan Water District of Southern California, Los Angeles.

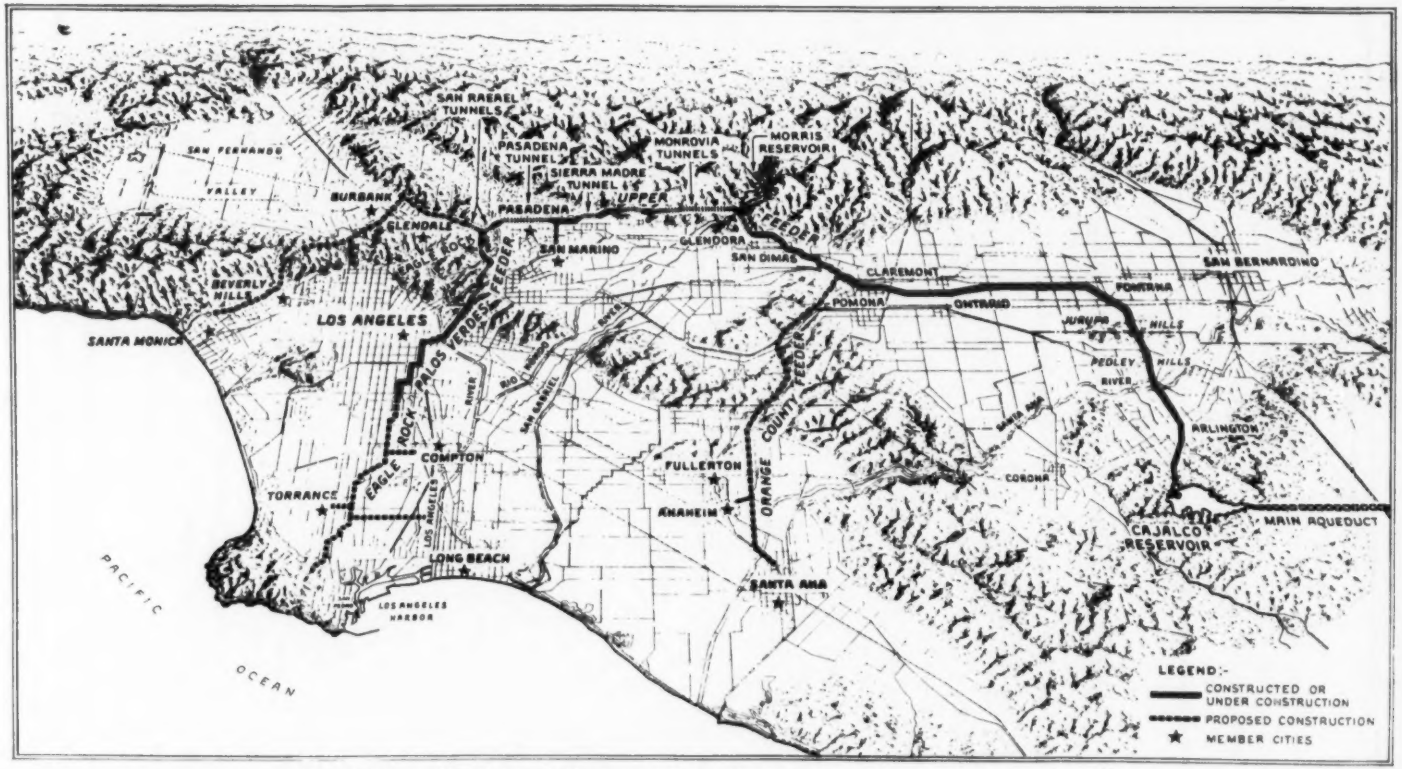


FIG. 1. Map of initial installation of Colorado River Aqueduct, November 8, 1938

varying from 141 to 441 feet. Power will be purchased from the government plant at Boulder.

Cajalco Reservoir will be connected to the water systems of the various cities by a system of pressure lines. These lines are for wholesale deliveries only, as the District will make no sales directly to consumers. This feeder system will ultimately consist of two main lines out of Cajalco, with spreading branches toward their western ends to reach all of the areas to be served by the aqueduct. One of these main lines, known as the Upper Feeder, runs north from the reservoir to Fontana, and then west along the foothills through Glendora, Sierra Madre, and Pasadena, to Eagle Rock canyon on the eastern edge of Glendale. The second main line will run directly from Cajalco to the harbor area.

As the full flow of both these main lines will not be required for many years, only the upper line is being constructed at the present. This line, which has been completed, has sufficient capacity to serve the estimated ultimate needs of the higher areas of the District. For many years there will be surplus capacity which will be utilized temporarily to supply the needs of the lower areas, thus permitting several years' deferment of the lower main feeder.

This discussion is limited to the completed Upper Feeder and one of its principal laterals, now under construction. A map of the initial installation is shown as fig. 1. The main feeder has a total length of 62.5 miles, composed of 10.3 miles of steel pipe, 36.0 miles of concrete pipe, and 16.2 miles of tunnel. The designed capacity is 750 c.f.s. from Cajalco to San Dimas, and 510 c.f.s. from San Dimas to Eagle Rock, based on values of .014 and .012 for Manning's n, in enameled steel and pre-cast concrete pipes, respectively.

The take-out from Cajalco is by a 14-foot tunnel through the northern rim of the basin. Flow into the tunnel will be controlled by fifty 30-inch hydraulically-operated gate valves, so distributed in an outlet tower as to permit selective withdrawal. A set of free discharge regulating valves at the tunnel outlet affords a duplicate control.

Beyond the outlet structure, the line is in pressure pipe for 41.5 miles, until it encounters the mountains flanking the San Gabriel River. Here four 10-foot diameter circular tunnels, with a total length of 9.3 miles, are required for piercing the mountains and connecting the line with Morris Reservoir. The pressure line is again interrupted by tunnel in the cities of Sierra Madre and Pasadena, and in the San Rafael Hills west of the Arroyo Seco.

The Monrovia and San Rafael Tunnels were practically necessary as the mountains they pierce could not conveniently have been avoided. The Sierra Madre and Pasadena Tunnels, which are at depths of 30 to 70 feet below the ground surface, were deliberately substituted for pipe line in open trench to avoid congestion and inconvenience in densely populated areas. Alternative bids showed the cost of pipe and tunnel to be almost identical. All of the distribution system tunnels are designed to operate under pressure.

In both the Pasadena and Sierra Madre Tunnels, the ground encountered was partially cemented alluvium which was readily excavated without blasting by means of pneumatic spaders and electric powered mucking machines. The ground was supported throughout using steel bents, fabricated from 5-inch I-beams, with backing of tight timber lagging and spiling.

The concrete lining of these tunnels was reinforced with circumferential steel bars to withstand the maximum internal pressure varying from 25 to 110 feet of head. Full circle lining was placed without longitudinal construction joints in sections 60 to 80 feet long, utilizing special collapsible steel forms which were supported by a traveling carrier. Pneumatic concrete guns were employed in placing the concrete behind the forms. As it was not possible to remove lagging and spiling in the alluvium due to danger of caving and sand runs, voids behind the lagging and spiling were filled with grout.

The Monrovia and San Rafael Tunnels were through rock and the excavation work involved the usual cycle of drilling, blasting, and mucking. In most places only light support was used, consisting of steel ribs and timber lagging; however, some soft and swelling ground was encountered where timber sets were necessary.

Concrete lining was placed in the rock tunnels in a manner similar to that employed in the alluvial tunnels except that in a portion of the 6-mile Monrovia No. 3 Tunnel, the placing of the invert lining in advance of the sides and arch was permitted to take care of a relatively large flow of water. Reinforcement steel was used in the rock tunnels where the depth of cover was less than twice the pressure head, or where soft unstable ground was encountered. Heads on the tunnels will range from 25 to 260 feet. The greatest head, 110 to 260 feet will be in the westerly 2,856 feet of the Monrovia No. 4 Tunnel. Here a steel cylinder liner of $\frac{1}{4}$-$\frac{7}{16}$-inch plates was used to give greater strength and insure water-tightness. This cylinder has

13 inches of concrete outside of it and is lined with 2 inches of gunite, which protects the steel.

After the completion of the concreting operations in the Monrovia and San Rafael Tunnels, grout was forced into the seams and voids back of the lining. In some places where the external hydrostatic head was great, high pressure grouting and the calking of construction joints with lead wool were required to shut off completely the inflow of groundwater.

Pre-cast Concrete Pipe

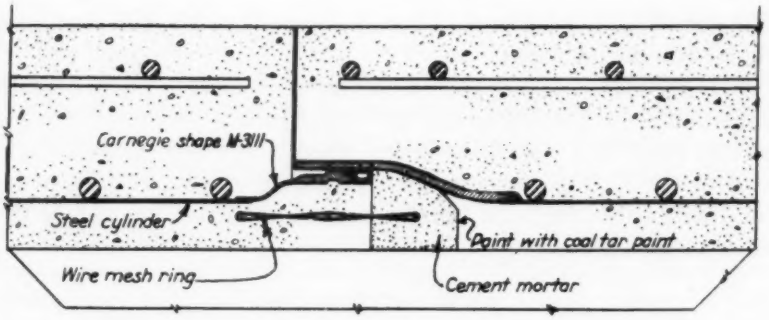
Except for a few monolithic canyon crossings, all of the 36.0 miles of concrete pipe on the Upper Feeder is pre-cast. Diameters ranged from 9 ft. 8 in. to 12 ft. 8 in., the largest pre-cast pressure pipe thus far attempted. Heads ranged from nominal up to 292 feet. Shell thickness varied from 10 to 13 inches. Backfill depths were from 4 to 20 feet over the top of the pipe. Reinforcing was computed for a combination of external and internal loading.

For heads less than 80 feet, a combination of circular and elliptical cages was used. For greater heads, a thin steel cylinder was added to the assembly for water-tightness. The cylinder steel was considered as available for resisting internal pressures, but was ignored in computing bending stresses because of doubtful bond strength. The bar reinforcement was of modified intermediate grade, delivered to the job in continuous coils. The pipes were cast vertically in 12-foot lengths. The joints used are shown in fig. 2. The mortar joint was used on $9\frac{1}{2}$ miles of low-head pipe. Elsewhere, steel and lead joints (Lock Joint Pipe Company type) were used, attached to bar cages or bar and steel cylinder cages, as required.

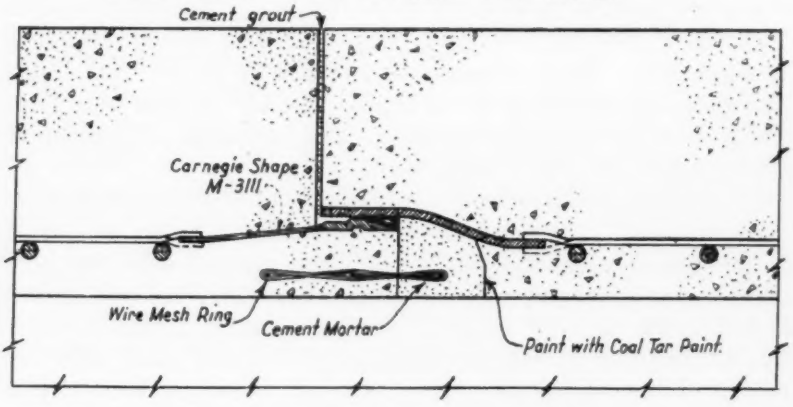
The pipe was installed under three separate contracts. Complete manufacturing and curing plants were established adjacent to the line. Procedures were similar in all essential respects.

Bar reinforcing was wound into cages on an electrically-driven drum (fig. 3) and welded to the longitudinal steel to form a unit which could be handled and which included the joint rings and the steel cylinder where used. A traveling crane as shown in fig. 4 handled the completed units into storage and into the forms.

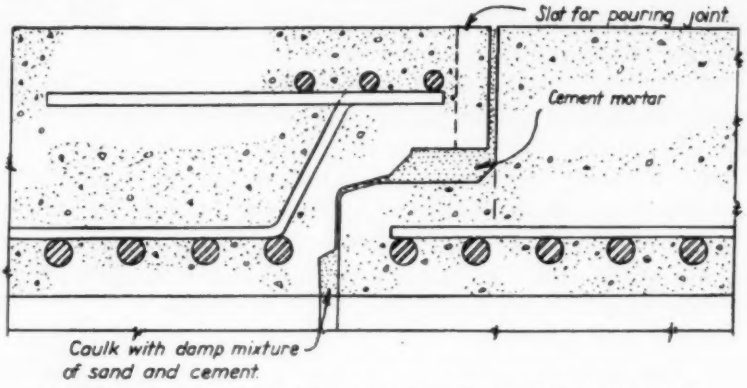
Cement and aggregates were brought to the job in cars or on trucks, handled and stored by standard methods, and automatically weighed out into four-cubic-yard batches. The mixed concrete was discharged into two-cubic-yard buckets resting on cars operating



LOCK JOINT FOR STEEL CYLINDER



LOCK JOINT FOR CAGE REINFORCEMENT



MORTAR JOINT FOR CAGE REINFORCEMENT

FIG. 2. Joints used on the Colorado River Aqueduct

on a railway track paralleling the casting yard. These buckets were lifted by a traveling crane and dumped into a hopper on a movable placing gantry, straddling the pipe form to be filled. The concrete was withdrawn from this hopper through a 12-inch-diameter swivel chute, revolved in such manner as to assure uniform filling of the form.

The concrete was moderately vibrated by stationary electric vibrators, clamped to the outside forms, but working was principally accomplished by a new and novel device. This device consists of

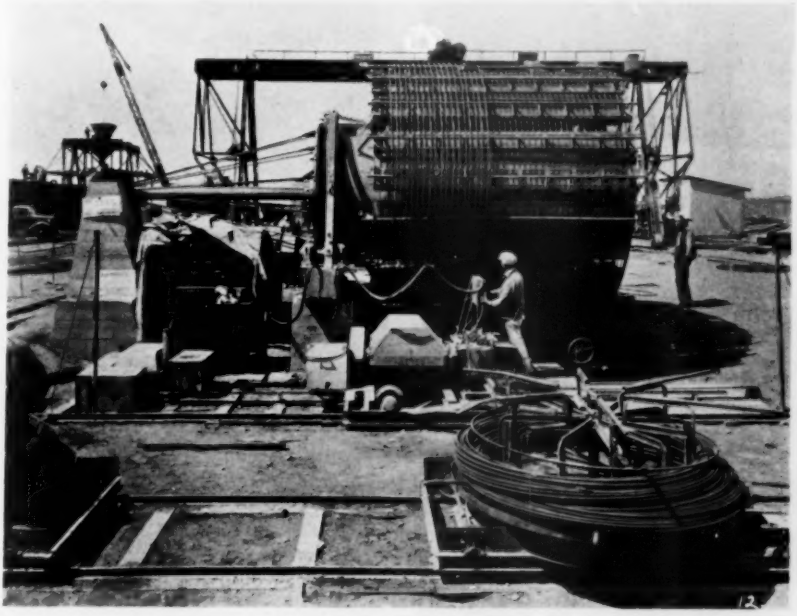


FIG. 3. Winding reinforcement cage, pre-cast pipe 12 ft. 8 in. in diameter

a ½-inch-square, spring steel rod about 3 feet longer than the depth of form and rotated at about 500 r.p.m. by a small air motor. The rotating rod is pushed down into the concrete along the face of the form. A slight kink near the lower end and a little manipulation by the operator cause it to creep along the face of the form. The entire inner and outer surfaces are treated in this manner. The resulting surfaces are very smooth and free from the air and water "pock marks" common where vibrated concrete is placed against high vertical forms. This treatment is reported to have cost a little

FIG. 4

FIG. 5

FIG. 4. (at left) Traveling crane, Santa Ana River Siphon
FIG. 5. (at right) Placing 42-ton pre-cast pipe section, American Concrete and Steel Pipe Co.

FIG. 6

FIG. 7

FIG. 6. (at left) Placer used by J. F. Shea Co., Inc.
FIG. 7. (at right) Crawler type crane used by U. S. Concrete Pipe Co.

less than one cent per square foot of surface treated. Patents covering this device are held in the western territory by the American Concrete and Steel Pipe Company of Los Angeles.

Forms were stripped after about 12 hours and the pipe was tipped off the base ring during the third day. The forms were handled by the same crane that handled the reinforcement and the concrete. The pipes were tipped by a hoist attached to the same gantry which carried the placing hopper.

The outer surfaces of the pipe were kept drenched after stripping until late afternoon or evening, and then sprayed while wet with two coats of coal tar cut back. The top of the pipe was closed by a portable cover and the inner surface was kept wet until tipping. After tipping, both ends were closed and the water curing continued for a period of 12 days, after which the pipe was ready for placing.

The cured pipe sections were rolled onto heavy trailers and transported to the trench where they were placed by special traveling equipment. The placer used by the American Concrete and Steel Pipe Company consisted of a steam-operated stiff-leg derrick mounted on a structural steel frame which traveled on a 48-foot gage track spanning the trench (see fig. 5). This placer was capable of handling 45 tons on a 36-foot radius. The heaviest pipe section weighed over 42 tons.

The placer used by the J. F. Shea Company is shown in fig. 6. It consisted essentially of two bridge-type trusses spanning the trench and traveling on rails laid to a 38-foot gage. The pipe was rolled between these trusses and lowered by slings from an electric hoist, movable in all directions. The lesser track width of this hoist gave a little trouble in caving ground but was necessary because many of this company's operations were in city streets where clearances were restricted.

The 9 ft. 8 in. and 10 ft. 3 in. diameter pipe furnished by the United Concrete Pipe Company were handled with a heavy crawler type crane pictured in fig. 7.

Although soil conditions were usually favorable, all of these large-diameter pre-cast pipes were bedded in concrete cradle.

The outside of the mortar type joints above the cradle were pointed with a stiff mortar. Strips of building paper were used on the lower section of the pipe to prevent cradle concrete from entering the joint. The inside joint was pointed to within one inch of the surface of the pipe. The inner space was then filled with a thin one-to-

three-cement and sand grout, poured in through a porthole in the outside top of the joint. Following completion of backfill operations, the inside joint was completely filled with mortar, and trowel finished.

The lead and steel joints were lightly calked when placed, then backfilled and allowed to settle before final calking. As a final operation, the calking space was filled with gunite.

After completion, all pipes were tested for leakage under full operating heads. The results are shown in table 1.

TABLE 1

Leakage tests on completed pipe lines

(In gallons per inch of diameter, per mile per day)

SCHEDULE*	DIAMETER	LENGTH	ACTUAL LEAKAGE LOSS		
			Welded steel pipe	Pre-cast concrete pipe—mortar joints	Pre-cast concrete pipe—lead and steel joints
	inches	*miles*			
1P	140	2.33			17
2S	116 to 138	10.33	7		
3P	140	3.81			12
4P	152	4.90		33	
5P	152	4.71		21	
6P	140	5.17			20
7P	140	5.64			31
8P	123	4.64			57
10P	116	1.99			27
11P	116	0.78			67
Leakage loss allowed by the specifications			15	100	100

* Successive lengths of the pipe line, running from Cajalco toward Eagle Rock.

Welded Steel Pipe

The 10.3-mile, high-head siphon across the Santa Ana River and the upper 17.4 miles of the lateral from Eagle Rock to Palos Verdes are of welded steel.

The head of the Santa Ana siphon varies from 20 feet to 485 feet, the pipe diameter from 9 ft. 8 in. to 11 ft. 6 in., and the shell thickness from $\frac{17}{32}$ to $\frac{31}{32}$ in. The line is buried in trench except where it crosses the river on a bridge (fig. 8). The diameters were determined by the economic slope theory and thicknesses were computed

for a shell stress of 13,500 lb. per square inch. The minimum plate thickness of $\frac{17}{32}$ in. was for sections under low heads, based on considerations of external loads and buckling strength.

The pipe was furnished and installed under contract with the Western Pipe and Steel Company, of Los Angeles. Excavation and backfill was sublet to Morrison-Knudsen Company, and a part of the pipe fabrication to the Consolidated Steel Corporation, Ltd., of Los Angeles. The pipe was fabricated in 33-foot lengths in Los Angeles. All shop welds were made by automatic machines. An

FIG. 8. Santa Ana River crossing during flood of April, 1938

interesting feature was the development by the Western Pipe and Steel Company of one-pass welding for plates up to $\frac{31}{32}$ in. in thickness, the maximum used in the line.

The essential features of the alternating current welding process used for this purpose are shown in fig. 9. The plate edges A and B were first tacked and then closed by a light hand-applied seal weld, as shown. In the machine, the pipe was supported by the copper welding strips, C, D, and E, the latter of which was water-cooled. The trough, F, was filled with a blanketing flux through which the welding rod, G, ploughed at about 10 inches per minute. Under proper control of amperage and voltage, the tack welds and the

seal weld were completely melted out and a full penetration of the plate was secured. The flux melted, excluding the air, holding the heat of the weld long enough to effect some annealing and producing other beneficial effects. The portion of the weld filling the groove in the plate, E, was chipped away to give a smooth interior finish.

For longitudinal joints, the trough, pipe, and backing-up strip were stationary, and the welding head movable. For roundabout joints, the head and water-cooled backing-up strip were stationary, and the pipe revolved.

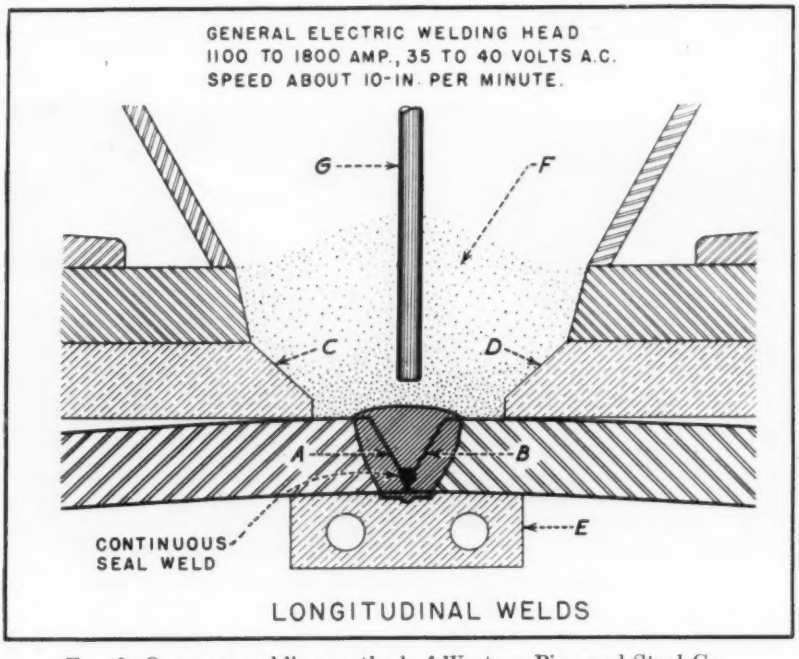


FIG. 9. One-pass welding method of Western Pipe and Steel Co.

The welding head used by the Consolidated Steel Corporation, Ltd., is shown in fig. 10. This head and the backing-up strip were stationary, the pipe traveling by them. The flux was fed onto the weld area from a hopper. This company made no attempt to get complete penetration at one pass on the Santa Ana River siphon, but chipped out the back side of the first weld and completed with a machine-placed direct current weld as indicated. For roundabout joints, the head was stationary and the pipe and backing-up strip revolved.

Where the plate thickness exceeded $\frac{5}{8}$ in., the welded pipe was moved into a closed furnace and annealed one hour per inch of thickness, at peak annealing temperature of not less than 1,100° F. Each pipe section, after completion, was tested hydraulically to a stress in the steel of 22,000 lb. per square inch.

The pipe was protected against corrosion by coal tar enamel on the inside and by a $\frac{3}{4}$ in. thick outside gunite coating as shown in fig. 11. For bad soil conditions, a coating of coal tar enamel also was used on the outside, beneath the gunite. The inside enamel was applied centrifugally in the shop over a sprayed-on priming

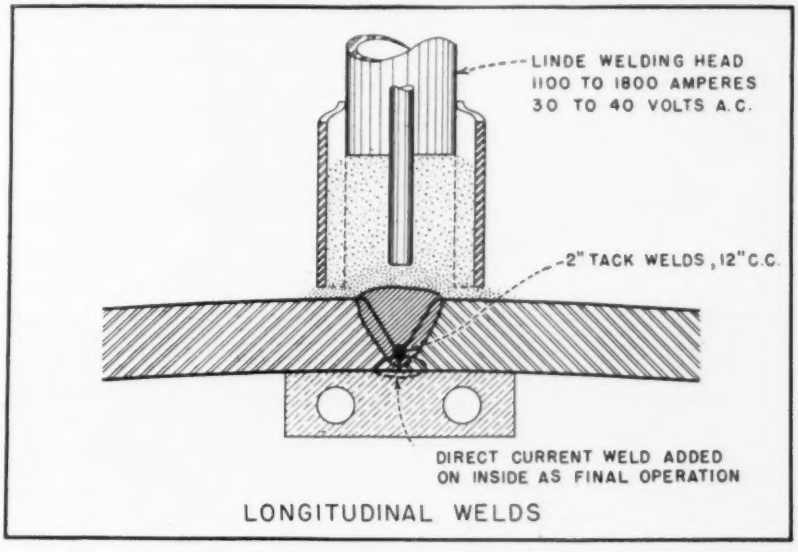

LINDE WELDING HEAD
1100 TO 1800 AMPERES
30 TO 40 VOLTS A.C.
2" TACK WELDS, 12" C.C.
DIRECT CURRENT WELD ADDED
ON INSIDE AS FINAL OPERATION
LONGITUDINAL WELDS

FIG. 10. Back side of first weld is chipped out in this method of the Consolidated Steel Corp.

coat. The enamel was selected by careful testing to insure stability and adherence under all likely temperature conditions. It was applied at a temperature of approximately 475°F. and at a peripheral spinning speed of about 1,100 feet per minute.

For best results, it was found necessary to preheat the steel pipe to a temperature of about 190°F. The enamel was heated in an electrically-controlled, gas-fired furnace, mounted on a car traveling along the projected center line of the spinning pipe, and was delivered through a cantilever spout having a 12-inch side weir at its outer end. The travel of the car and the spinning speed were ad-

justed for a 6-inch pitch, thus laying the enamel in a continuous double-spiraled ribbon. With careful application, the spirals were not apparent in the finished work.

Outside enamel was poured and spread by hand as the pipe was slowly revolved. Strips about 12 inches wide at each end, both inside and outside, were left for hand-daubing after the completion of the field welding. The enamel was approximately $\frac{1}{8}$ in. thick, as applied,

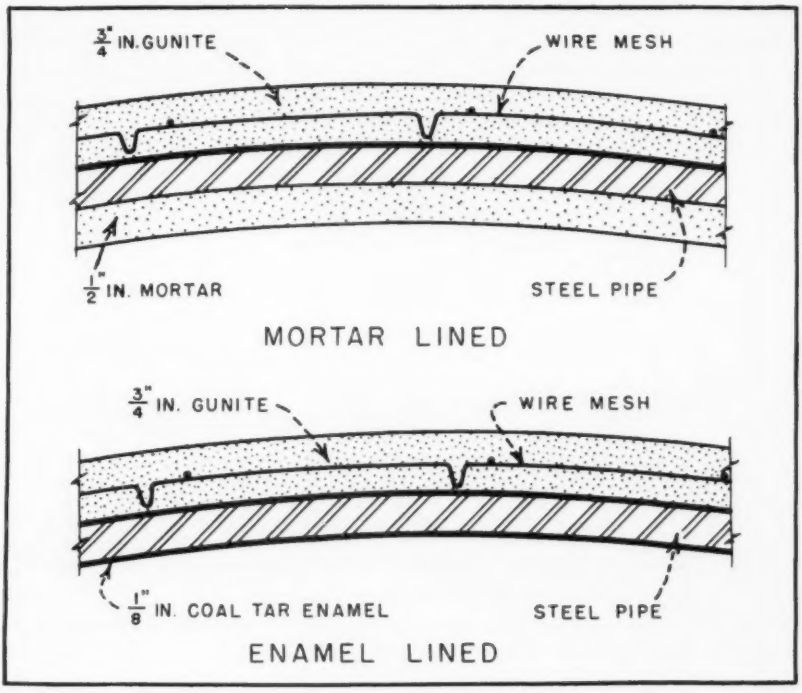


FIG. 11. Applications made for protection against corrosion

and on the inside presented an extremely smooth, mirror-like surface. The initial resistance to flow will be low. The value of .014 for n, used in design, allows for considerable deterioration with age.

The entire surface of the enamel, both inside and outside, was inspected by an electrical detector (fig. 12). The detector consisted of a broad wire brush, energized by a 5,000-volt, .012-ampere, electric current, supplied by a standard Neon transformer attached to a 110-volt, alternating current outlet. When this brush is passed

FIG. 12. Testing for imperfections in the enamel

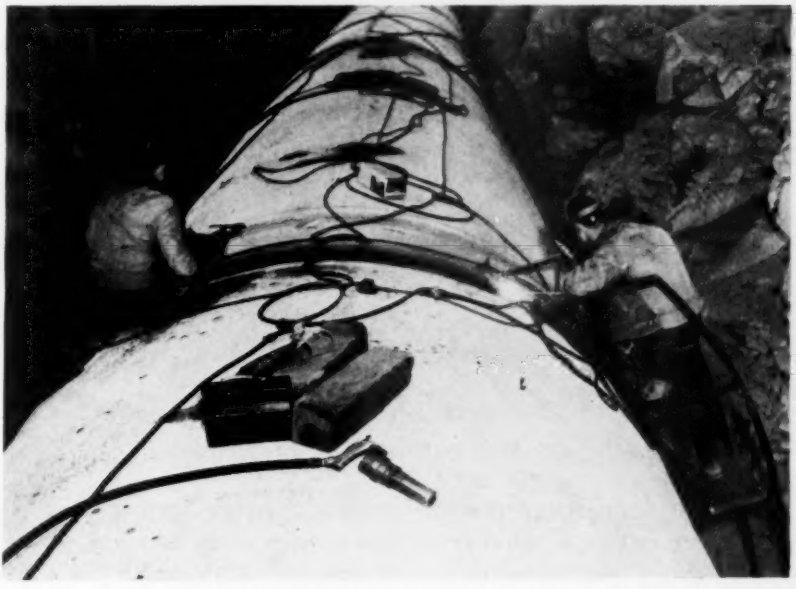


FIG. 13. Welding field joints, Santa Ana Siphon

over the enamel surface, imperfections are revealed by sparking. These imperfections are cut out and repaired by hand.

The enamel pipe sections were shipped to the field on flat cars, unloaded by a gasoline-propelled caterpillar gantry, and placed

FIG. 14. Two coats of gunite applied

on rolling supports preparatory to receiving the coating of gunite. As shown in fig. 14, self-furring welded wire mesh fabric, 2 in. by 4 in, 12 gauge, was stretched around the pipe, after which the gunite was applied in two coats. The gunite was water-cured until evening

of the day placed and then while still wet was protected by two coats of sprayed-on cut-back coal tar. This cut-back was coated with whitewash for temperature control.

After the gunite was cured for a minimum of 7 days, the pipe was loaded by the gantry onto trucks, transported to the trench, laid by an electric crane, and welded. All inside and outside field welds of the bell and spigot joints shown in fig. 15 were executed by hand, using portable direct current welding machines. The number of passes varied from 4 to 7, depending on the plate thickness. Each joint was provided with 4 taps and was tested by forcing a soap solution under 100 lb. pressure into the space between the two welds.

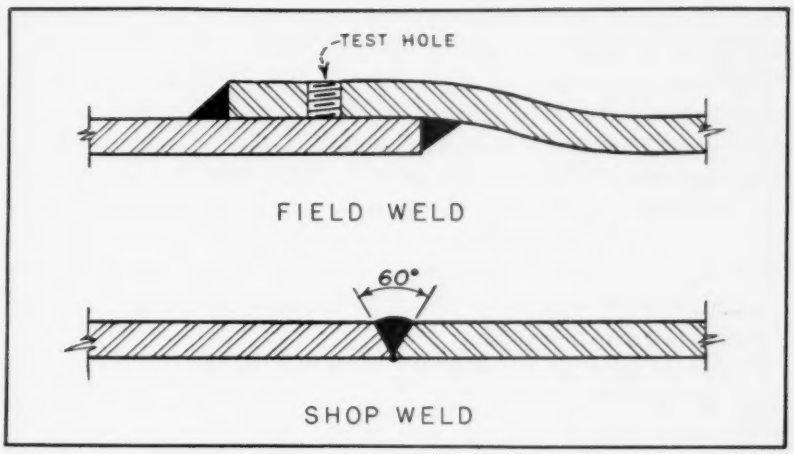


FIG. 15. Typical pipe welds, field welds done by hand

After testing, the enamel and gunite coatings were completed over the joint areas and the pipe was backfilled by puddling.

Work is now in progress on a contract with the J. F. Shea Company covering the northerly 17.4 miles of the Eagle Rock to Palos Verdes cross feeder. This cross feeder provides for serving water to Los Angeles, Long Beach, Torrance, and Compton. The northern portion traverses the eastern part of the City of Los Angeles and is located mainly in streets at a depth below other utility improvements. Maximum head on the line will be about 450 feet. Diameters of the welded steel pipe are 55 in. and 51 in., with plate thicknesses from $\frac{3}{8}$ to $\frac{15}{32}$ in.

Fabrication of the pipe into sections 30 feet long and application

of protective coatings have been sublet to the Consolidated Steel Corporation, Ltd., and these operations are being carried on at the Los Angeles plant of that company. The methods employed are quite similar to those used for the larger pipe at the Santa Ana River. A notable exception is that the pipe for the Eagle Rock to Palos Verdes feeder is being lined with cement and sand mortar to a thickness of $\frac{1}{2}$ in. The outside coating is the same as used on the Santa Ana siphon, namely $\frac{3}{4}$-inch gunite reinforced with wire mesh. In corrosive soils, a layer of coal tar enamel beneath the gunite is included.

The cement mortar lining is centrifugally applied by a spinning process, involving the use of rollers. The spinning machine has three rollers with solid rubber tires at each end of the pipe section, two on the bottom and one on the top. Four ring stiffeners are clamped on the outside of the section before spinning, in order to prevent deflection. The mortar is carried into the pipe by means of a hopper which extends the full length of the section. With the pipe revolving at a peripheral speed of about 900 feet per minute, the mortar is dumped onto the steel by slowly tipping the hopper. The hopper is then withdrawn and the peripheral speed increased to a maximum of about 3,600 feet per minute. This maximum speed is maintained for a period of about 20 minutes, after which the pipe is removed from the machine.

About one hour after the spinning has been completed, the surface of the mortar is hand-troweled to a smooth hard finish. Each section is then bulkheaded, and the mortar is cured by an automatically operated water spray. Hand troweled gunite is used for the inside lining at the field joints.

In order to prevent damage to the mortar lining due to deflection of the pipe caused by the backfill, water at a pressure of about 20 lb. per square inch is maintained in the line during backfilling operations and thereafter until the backfill becomes consolidated. For this purpose, steel bulkheads are installed in the line at intervals of about 1,000 feet.

Special precautions are being taken to prevent electrolytic action in the steel pipe because of the numerous street railway and utility lines that are crossed. In addition to insulating the pipe with gunite, and coal tar enamel where required, two insulating joints and several electrolysis test connections are being installed on the 17-mile stretch.

British Grounding Regulations

Introduction

IT HAS for many years been a common practice to utilize incoming water-mains for the earthing of electrical installations.[1] Cases have arisen, however, where corrosion of water-mains has been attributed to such earthing. It is known, for example, that continuous current causes electrolytic corrosion where it leaves a metal conductor or pipe to enter the earth, but the effect of the passage of alternating current to earth is somewhat obscure. A further point in connexion with earthing is that there have been instances where electric shocks have been incurred during the repair of water-mains.

It was obvious that some agreement as to the conditions under which earthing-connexions should be made was desirable, and the question was considered by a Joint Committee of the Institution of Electrical Engineers and the Metropolitan Water Board, as a result of which a draft memorandum on Earthing to Water-Mains was issued on the 20th of December, 1926. It was not possible, however, to conclude the negotiations on that occasion.

The need for such agreement became increasingly evident, and it was in these circumstances that a Sub-Committee of the Institution of Civil Engineers Research Committee was formed in March 1936, to explore the problem of possible injury to metal water-pipes and

Reprinted by permission of E. Graham Clark, Secretary, The Institution of Civil Engineers, Great George Street, London, from the Journal of the Institution of Civil Engineers, No. 8, p. 573, October, 1938. The full title is: Regulations for Controlling the Earthing of Electrical Installations to Metal Water-Pipes and Water-Mains, Drawn up and Approved by The Institution of Civil Engineers, The Institution of Electrical Engineers, The Institution of Water Engineers, The British Waterworks Association, and The Water Companies' Association.

[1] As defined by the Electricity Supply Regulations, 1937, for Securing the Safety of the Public . . . Clause 29 (*a*) (i): i.e. All metal work enclosing supporting or associated with the consumer's installation, other than that designed to serve as a conductor.

mains through the earthing thereto of electrical installations, particularly in relation to alternating currents, with a view to

(*a*) investigating the existence and extent of such injury, research being carried out if necessary;

(*b*) obtaining mutual agreement on the conditions under which earthing-connexions to metal water-pipes and water-mains might be made; and

(*c*) if necessary, formulating a set of regulations in respect thereof.

The Sub-Committee includes nominees of the Institution of Electrical Engineers, the Institution of Water Engineers, the British Waterworks Association and the Water Companies' Association, and acknowledgment is here made of the valuable assistance which they have rendered.

The Sub-Committee have taken into consideration the memorandum drawn up by the above Joint Committee, and they have been successful in securing unanimous agreement on the conditions under which earthing-connexions may be made in recommending the following Regulations in respect thereof.

The Regulations are intended to be applicable generally, with one exception: Post Office installations other than those for power and lighting services are excluded from the application of these Regulations, but are subject to agreement between the authorities concerned.

In the course of their work the Sub-Committee came to the conclusion that there were certain other aspects of the problem which could with advantage form the basis of research. The Institution gratefully acknowledges the funds which have been subscribed for such research by the interests concerned, and the investigation has been undertaken by the British Electrical and Allied Industries Research Association. The programme of research so far approved is as follows:—

(i) The amount and effect of aggregate leakage-currents on water-pipes.

(ii) The possibility of partial rectification of alternating currents in underground water-supply systems

  (*a*) at earthing-connexions;

  (*b*) between metal pipes and the soil.

(iii) The possibility of primary-cell effects in water-supply systems.

(iv) The relation of the above to the question of corrosion.

Regulations

Preamble. These Regulations have been drafted under the auspices of the Institution of Civil Engineers as the result of agreement come to between representatives of Water and Electrical Interests. They are subject to any amendment which may be shown to be desirable as a result of further experience or research.

Clause 1. An earth-wire connecting an electrical installation to a water-main or water-pipe is to be used only:—

(*a*) as a measure of safety for the purpose of returning to the source of supply such leakage current as may flow, or result from a failure of insulation.

(*b*) for radio-frequency currents and those from radio-interference-suppression devices.

Clause 2. A water-main or water-pipe shall not be cut, drilled or broken, for purposes of Clause 1, and all reasonable and proper care shall be exercised, in making any earth-connexion, to prevent injury or damage to a water-main or water-pipe.

Clause 3. Every earth-connecting device to a water-main or water-pipe shall be of such an approved design[2] as to ensure an efficient electrical connexion, and other than as provided for in Clause 4 shall be attached in a position convenient for, and easy of, access.

Clause 4. An earth-connexion shall only be made to a buried water-main or water-pipe after notice to, and in a manner approved by, the water authority concerned.

Clause 5. Wherever an earth-connexion is made to a water-main or water-pipe on any premises in which is installed a water-meter, a proper, sufficient, and suitable bond shall in all such cases be placed across such water-meter by the user of the meter, free of expense to the water authority.

Clause 6. Where the water-supply authority has reason to believe that damage to water-mains or water-pipes is being caused by an excessive flow of current from an earth-connexion made to a water-main or water-pipe they shall, in general, request the electricity-supply undertakers for the district to test the installation, arrangements being made for a representative of the water-supply authority to be present at the time the test is made. If, however, for any

[2] For the purposes of Clause 3 the approval of the design of the earth-connecting device should rest with a joint committee of electrical and water representatives.

reason the water-supply authority should desire to test for electrical leakage from an installation to water-mains or water-pipes, that authority will be at liberty to make such test after advising the electricity-supply undertakers for the district of their intention, giving such notice to the consumer as may be necessary, and inviting the presence of a representative of the electrical undertakers when the test is made.

Water-supply authorities (whilst maintaining the powers which they are advised are conferred by existing water-supply legislation to enter premises, and if necessary to test for electrical leakage) agree that, in general, tests for electrical leakage, and any notice to the consumer which may be necessary in connexion therewith, should be made and given by the electricity-supply undertakers, who will usually possess the better facilities.

Note. Attention is drawn to the fact that in certain cases non-metallic water-pipes are in use, and the electrical implications of this should be recognized.

Graphic Determination of Carbon Dioxide and the Three Forms of Alkalinity

By Edward W. Moore

IN THE chemical analysis of water to be used for domestic or industrial purposes, it is often necessary to evaluate the quantities of free carbon dioxide, and of bicarbonate, normal carbonate and hydroxide alkalinity present in the water. Recent literature has indicated some dissatisfaction with the methods commonly used to determine these substances.[1] The tendency of the sodium hydroxide titration method to overestimate the carbon dioxide content of water when only a few parts per million are present has been noted by De Martini (1). For waters containing large amounts of carbon dioxide, conversely, the titration method underestimates the amount present, because of loss of carbon dioxide to the atmosphere during titration. The end-point of the titration is not altogether satisfactory, as it fades on standing.

The assumptions that form the basis of the phenolphthalein-methyl orange alkalinity titration have been questioned by other workers, particularly in the field of boiler water chemistry (2, 3, 4). One of the basic assumptions, namely, that neither carbon dioxide and normal carbonate, nor bicarbonate and hydroxide may exist together in the same water, certainly is not quantitatively accurate. There appears also to be a tendency, similar to that in the carbon dioxide test, to overestimate small values of phenolphthalein alkalinity. Furthermore the values for hydroxide alkalinity obtained by this method do not always agree with the hydroxyl ion content as computed from the hydrogen ion concentration of the water. For example, the phenophthalein and methyl-orange titration method

A contributed record of research by Edward W. Moore, Asst. Prof. San. Chem., Harvard Graduate School of Engineering, Cambridge, Mass.

[1] Carbon dioxide by titration with sodium hydroxide in the presence of phenolphthalein; bicarbonate, etc. by titration with standard acid in the presence of phenolphthalein and methyl orange.

often indicates no hydroxide alkalinity in a water of pH 10.0, yet we know that a water with this pH must contain approximately 5 p.p.m. of hydroxyl ion expressed as calcium carbonate.

It is possible to calculate from the hydrogen ion concentration and total alkalinity of a water, the amounts of carbon dioxide, bicarbonate, normal carbonate and hydroxide contained therein (5–13). De Martini (ref. 1, p. 108) has recently presented all the necessary equations, in a form sufficiently complete to be practically useful over a wide range of hydrogen ion concentration.[2] These equations are based on the ionization equilibria of the carbonates and water, and include three constants: K_1, K_2, and K_w. The most recent determinations of the constants K_1 and K_2, the first and second ionization constants of carbonic acid, are those of MacInnes and Belcher (14), who assign to them the values 4.54×10^{-7} and 5.61×10^{-11} respectively, at 25°C. The commonly accepted value of K_w, the ion product of water, at this temperature, is 10^{-14}. If these values are substituted in the equations of De Martini, and all concentrations are converted to more familiar units, we obtain the following equations:

$$(1) \qquad (CO_2) = 9.70 \times 10^{10}(H^+) \times \frac{\left[\frac{Alk}{50{,}000} + (H^+) - \frac{10^{-14}}{(H^+)}\right]}{1 + \frac{11.22 \times 10^{-11}}{(H^+)}}$$

[2] De Martini's equations are as follows:

$$(HCO_3^-) = \frac{\left\{Alk + (H^+) - \frac{K_w}{(H^+)}\right\}}{1 + 2\frac{K_2}{(H^+)}}$$

$$(CO_3^=) = \frac{K_2}{(H^+)} \times \frac{\left\{Alk + (H^+) - \frac{K_w}{(H^+)}\right\}}{1 + 2\frac{K_2}{(H^+)}}$$

$$(H_2CO_3) = \frac{(H^+)}{K_1} \times \frac{\left\{Alk + (H^+) - \frac{K_w}{(H^+)}\right\}}{1 + 2\frac{K_2}{(H^+)}}$$

$$(OH^-) = \frac{K_w}{(H^+)}$$

"Alk" alkalinity is in equivalents of titratable base per liter. All other quantities are in mols per liter.

$$(2)\quad (HCO_3^-) = \frac{50{,}000 \times \left[\frac{Alk}{50{,}000} + (H^+) - \frac{10^{-14}}{(H^+)}\right]}{1 + \frac{11.22 \times 10^{-11}}{(H^+)}}$$

$$(3)\quad (CO_3^=) = \frac{5.61 \times 10^{-6}}{(H^+)} \times \frac{\left[\frac{Alk}{50{,}000} + (H^+) - \frac{10^{-14}}{(H^+)}\right]}{1 + \frac{11.22 \times 10^{-11}}{(H^+)}}$$

$$(4)\quad (OH^-) = \frac{5 \times 10^{-10}}{(H^+)}$$

In these equations, (HCO_3^-), $(CO_3^=)$, (OH^-), and (Alk)[3] are in p.p.m. as calcium carbonate, (CO_2) in p.p.m. as carbon dioxide, and (H^+), hydrogen ion concentration, in mols per liter, the latter obtainable directly from the pH of the water.[4] The right-hand side of each equation contains only the total alkalinity and the hydrogen ion concentration of the water. Consequently the bicarbonate, normal carbonate, and hydroxide alkalinity, and the carbon dioxide of any water may be computed from these two quantities.

Graphical Representations of Equations

It is apparent that direct computation from the equations is somewhat laborious. However, for any given value of the hydrogen ion concentration, each of the equations may be plotted as a straight line, and they are therefore well adapted for graphical representation. The necessary diagrams are shown in figs. 1, 2, 3, 4 and 5. Figure 1 gives the relationship between pH, total alkalinity, and carbon dioxide (equation 1). Figure 2 presents the corresponding relationship for bicarbonate alkalinity (equation 2). Figures 3 and 4 depict the normal carbonate alkalinity (equation 3). Two figures are used in this case because the crossing of the lines renders a single diagram confusing. Figure 5 represents the hydroxide alkalinity, which is determined only by the pH (equation 4). These figures give by inspection, the bicarbonate, normal carbonate, and hydroxyl alkalinities, and the carbon dioxide content of any water of known pH and total alkalinity.

[3] Alk = Alkalinity

[4] $pH = \log \frac{1}{(H^+)}$

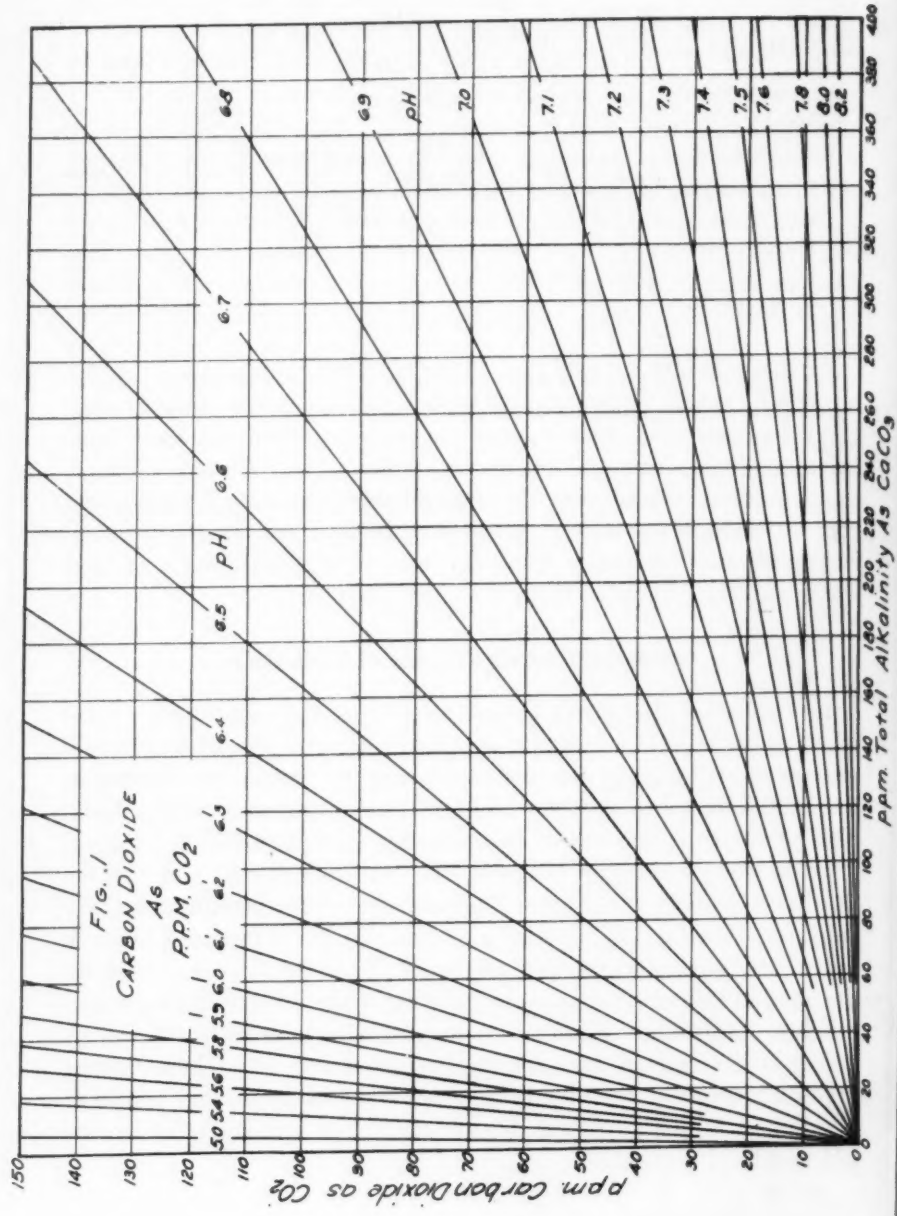


FIG. 1
CARBON DIOXIDE AS P.P.M. CO_2
pH
6.3
6.4
6.5
6.6
6.7
6.8
6.9
7.0
7.1
7.2
7.3
7.4
7.5
7.6
7.8
8.0
8.2
p.p.m. Carbon Dioxide as CO_2
p.p.m. Total Alkalinity As $CaCO_3$

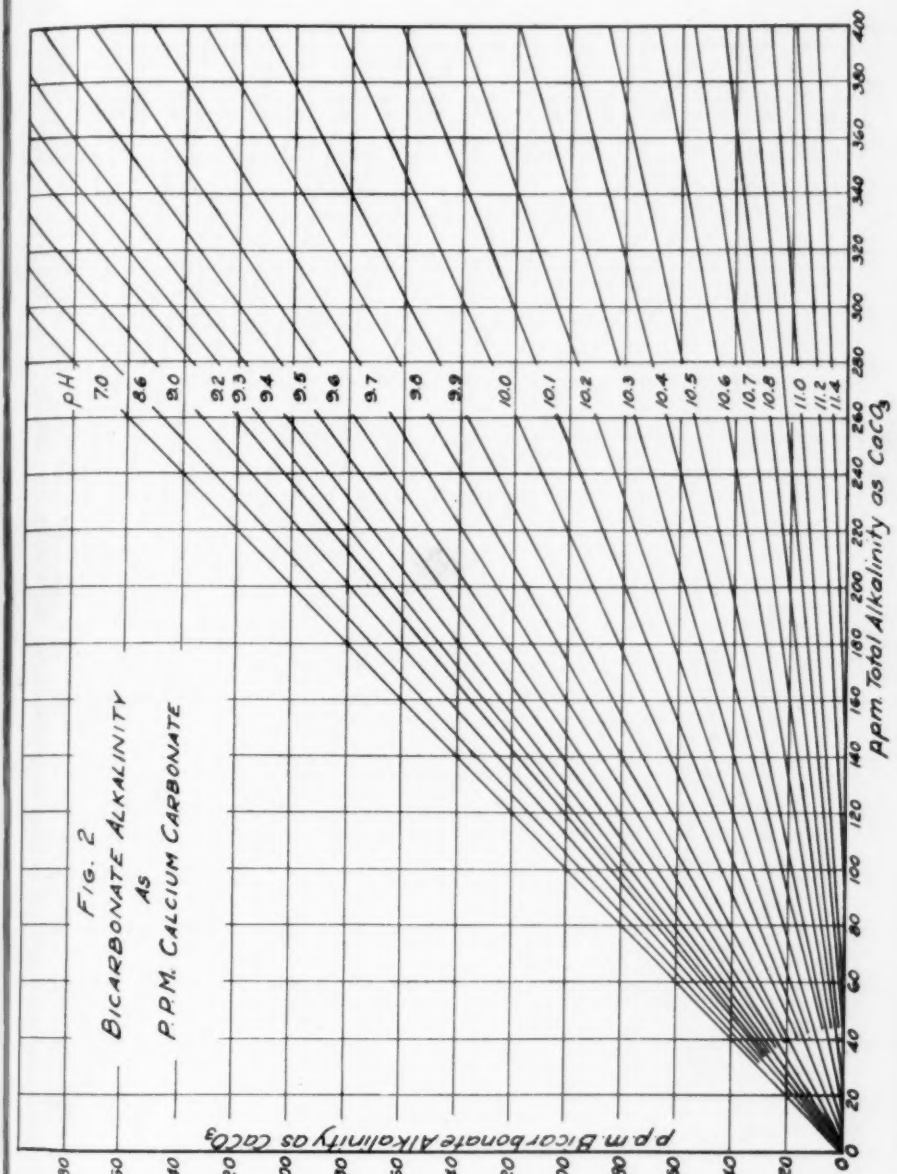
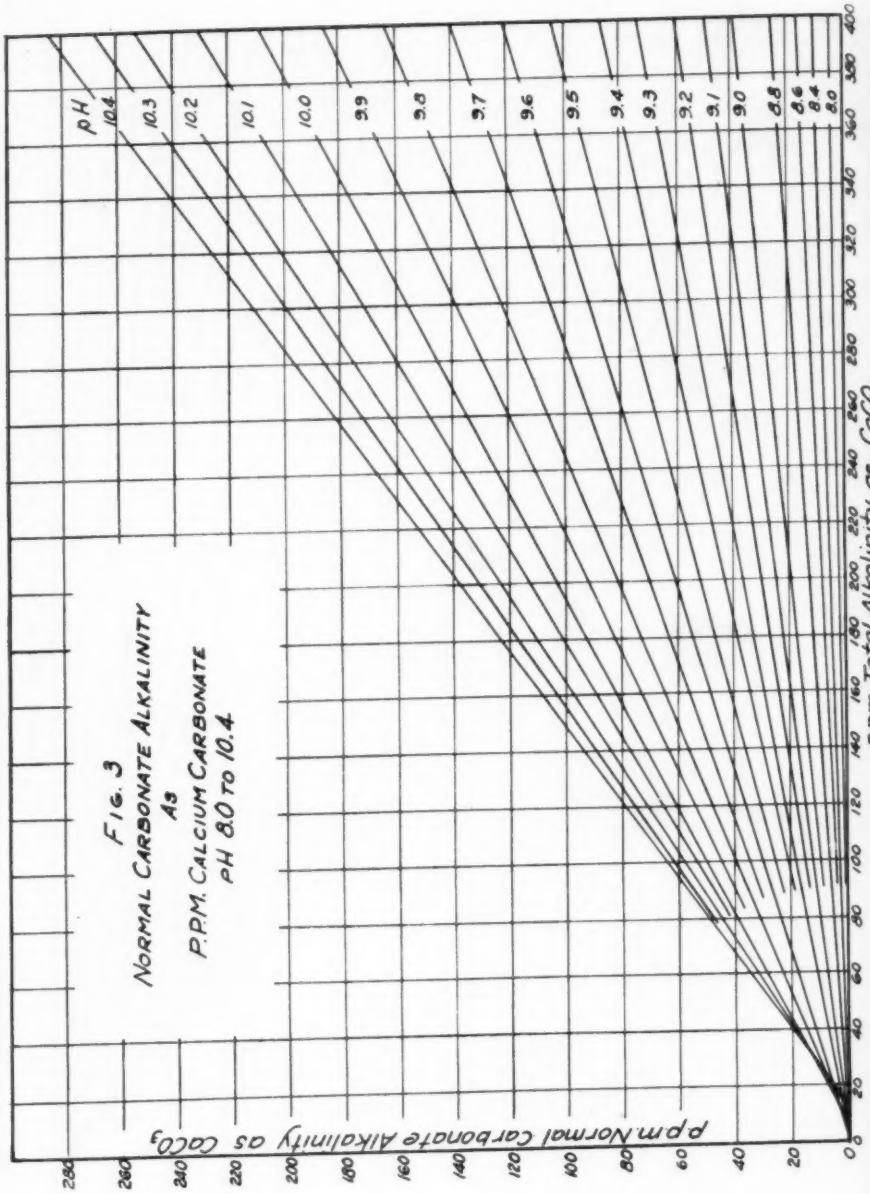


FIG. 2
BICARBONATE ALKALINITY
AS
P.P.M. CALCIUM CARBONATE


pH
10.4
10.3
10.2
10.1
10.0
9.9
9.8
9.7
9.6
9.5
9.4
9.3
9.2
9.1
9.0
8.8
8.6
8.4
8.0
FIG. 3
NORMAL CARBONATE ALKALINITY AS
P.P.M. CALCIUM CARBONATE
PH 8.0 TO 10.4
P.p.m. Normal Carbonate Alkolinity as $CaCO_3$
P.p.m. Total Alkalinity as $CaCO_3$

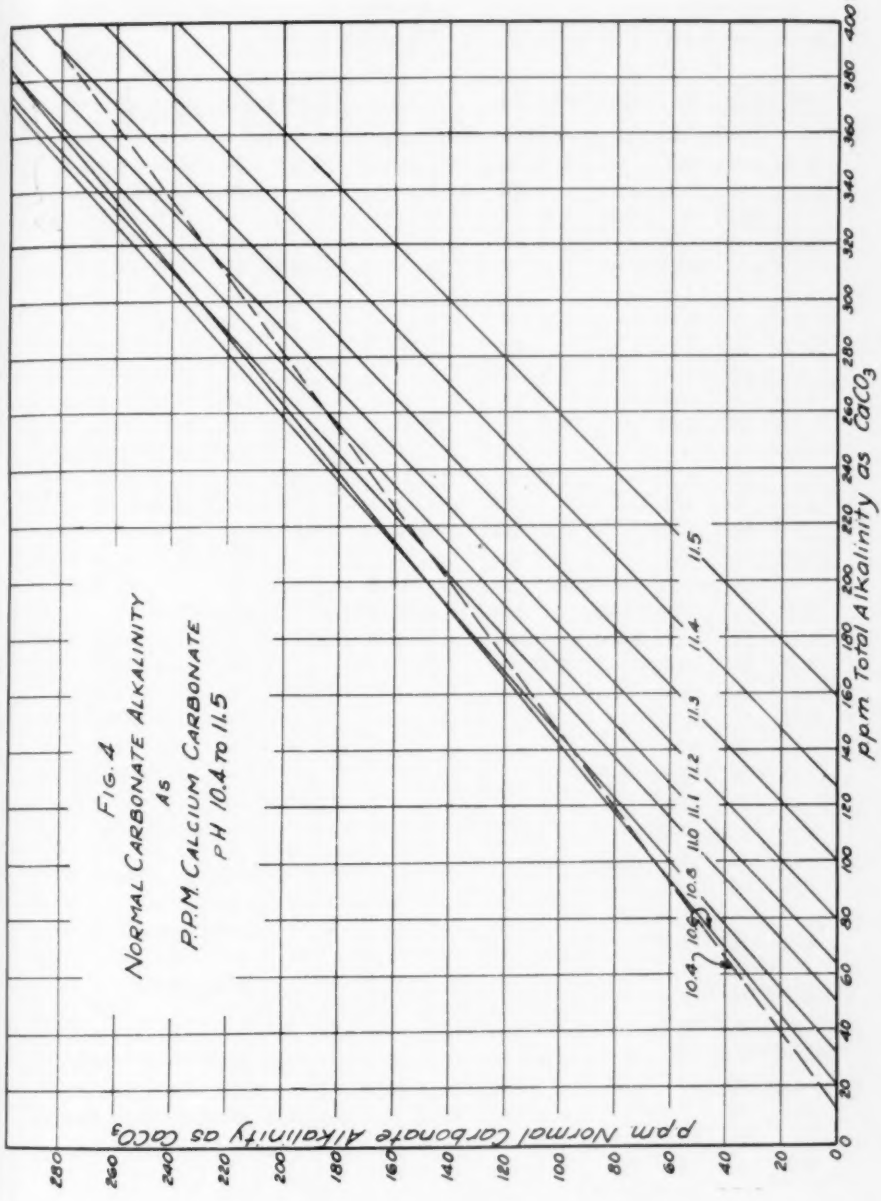


FIG. 4
NORMAL CARBONATE ALKALINITY AS P.P.M. CALCIUM CARBONATE PH 10.4 TO 11.5
p.p.m. Total Alkalinity as $CaCO_3$
p.p.m. Normal Carbonate Alkalinity as $CaCO_3$
10.4
10.5
10.6
11.0
11.1
11.2
11.3
11.4
11.5

TABLE 1

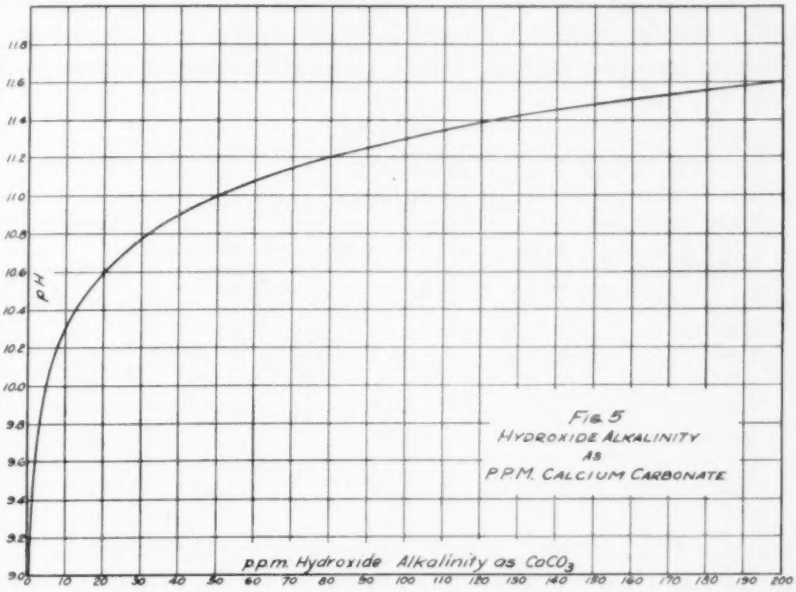
Data for Construction of Graphs

Bicarbonate, normal carbonate, hydroxide, and total alkalinity are expressed as p.p.m. $CaCO_3$, carbon dioxide as p.p.m. CO_2.

pH	TOTAL ALK.	(CO_2)	(HCO_3^-)	pH	TOTAL ALK.	(CO_2)	(HCO_3^-)	($CO_3^=$)	pH	TOTAL ALK.	(HCO_3^-)	($CO_3^=$)	(OH^-)
5.0	0	9.7	.5	7.2	50	6.1	—	—	9.6	50	33.2	14.8	2.0
	2	48.5	2.5		200	24.5	—	—		150	102.3	45.7	2.0
	100	—	100.5	7.3	50	4.9	—	—	9.7	50	30.4	17.1	2.5
5.2	0	4.9	—		200	19.4	—	—		150	94.3	53.2	2.5
	5	66.2	—	7.4	50	3.9	—	—	9.8	50	27.4	19.4	3.2
5.4	0	1.5	—		200	15.6	—	—		150	85.9	60.9	3.2
	5	40.3	—	7.5	50	3.1	—	—	9.9	50	24.4	21.7	3.9
5.5	0	1.0	—		200	12.2	—	—		150	77.2	68.9	3.9
	10	61.8	—	7.6	50	2.4	—	—	10.0	50	21.2	23.8	5.0
5.6	0	0.6	—		200	9.7	—	—		150	68.2	76.8	5.0
	10	49.3	—	7.7	50	1.9	—	—	10.1	50	18.1	25.6	6.3
5.7	0	0.4	—		200	7.7	—	—		150	59.5	84.2	6.3
	10	38.9	—	7.8	50	1.5	—	—	10.2	50	15.1	27.0	7.9
5.8	0	0.2	—		200	6.1	—	—		150	51.1	91.0	7.9
	10	30.9	—	7.9	50	1.2	—	—	10.3	50	12.3	27.7	10.0
5.9	0	0.1	—		200	4.8	—	—		150	43.1	96.9	10.0
	20	49.0	—	8.0	20	—	19.7	—	10.4	50	9.8	27.7	12.5
6.0	10	19.5	10.05		100	1.9	98.9	1.1		150	36.1	101.4	12.5
	20	38.9	20.05		200	3.8	198.0	2.2	10.5	50	7.5	26.7	15.8
6.1	10	15.4	—	8.2	100	1.2	—	—		150	29.6	104.6	15.8
	30	46.3	—		200	2.4	—	—	10.6	50	5.5	24.6	19.9
6.2	10	12.3	—							150	23.8	106.3	19.9
	30	36.8	—			(HCO_3^-)	($CO_3^=$)	(OH^-)	10.7	50	3.8	21.2	25.0
6.3	10	9.7	—							150	18.8	106.2	25.0
	30	29.2	—	8.4	100	97.3	2.8	—	10.8	50	2.3	16.2	31.5
6.4	10	7.7	—		200	194.5	5.5	—		150	14.6	103.9	31.5
	50	38.7	—	8.6	100	95.5	4.3	—	10.9	50	1.0	9.2	39.8
6.5	10	6.1	—		150	143.0	6.3	—		150	11.2	99.0	39.8
	100	61.4	—	8.8	50	46.5	3.3	—	11.0	50	0	0	50.0
6.6	10	4.9	—		150	140.0	9.9	—		200	12.3	137.7	50.0
	100	48.8	—	9.0	50	44.5	5.0	0.5	11.1	100	2.4	34.6	63.0
6.7	10	3.8	—		150	134.5	15.0	0.5		200	9.0	128.0	63.0
	100	38.7	—	9.1	50	43.4	6.0	0.6	11.2	100	1.1	19.6	79.3
6.8	10	3.1	—		150	131.0	18.4	0.6		200	6.4	114.3	79.3
	100	30.7	—	9.2	50	41.9	7.4	0.7	11.3	100	0	0	100.0
6.9	10	2.4	—		150	126.8	22.5	0.7		200	4.3	95.7	100.0
	100	24.4	—	9.3	50	40.1	9.0	0.9	11.4	150	0.8	23.6	125.6
7.0	50	9.7	50		150	121.9	27.2	0.9		200	2.6	71.8	125.6
	200	38.7	200	9.4	50	38.1	10.7	1.2	11.5	170	—	11.7	158.3
7.1	50	7.7	—		150	116.1	32.7	1.2		200	1.0	40.7	158.3
	200	30.8	—	9.5	50	35.7	12.7	1.6					
					150	109.5	38.9	1.6					

For the benefit of those who may wish to construct and use these diagrams, there is given in table 1 a sufficient number of computed values of all the quantities for a wide range of values of pH.

In the colorimetric determination of pH, results are customarily reported to the nearest 0.1 of a pH unit, although a few workers report results to 0.05 of a unit. If the pH is determined electrometrically, a somewhat greater precision may be obtained, but electrometric methods are not widely used in most water laboratories. Therefore the pH value, which largely controls the precision obtainable by the



use of the diagrams, may be regarded as normally uncertain to 0.05 of a pH unit.

The influence of this uncertainty on the precision of the values of carbon dioxide and the alkaline constituents obtained from the graphs cannot be stated simply, but varies in a complex manner for different combinations of pH and alkalinity. Table 2 shows the percentage of error produced by an error of 0.05 pH unit for the pH range 6.0 to 10.0 and a total alkalinity of 10 p.p.m. For alkalinities greater than 10 p.p.m., the percentages of error will be the same or somewhat smaller. For pH values outside this range, simplification is impossible, and the percentage of error to be expected is best estimated directly from the diagrams for each individual case.

Accuracy of the Diagrams

The accuracy of the diagrams, that is, the agreement between the indicated values of carbon dioxide, etc., and the quantities of these substances actually present in the water could be determined absolutely only by employing more accurate analytical methods than those used in practice. This, however, would be a laborious procedure. An approximate check on accuracy may be obtained by comparing the results of careful analyses by the customary methods, with those obtained from the use of the diagrams.

A comparison between the indicated and determined values of carbon dioxide content for water samples selected at random from the literature does not always show good agreement between the two

TABLE 2

Percentage of Error Produced by an Error of 0.05 in the pH Measurement

(Total Alkalinity 10 p.p.m.)

pH RANG	PERCENTAGE OF ERROR IN			
	(CO_2)	(HCO_3^-)	(CO_3^-)	(OH^-)
6.0- 7.0	10.2-11.2			
7.0- 8.0	11.2-11.5	0.0		
8.0- 9.0		0.0- 1.8	11.2-9.2	11.2
9.0- 9.5		1.8- 4.9	9.2-6.4	11.2
9.5-10.0		4.9-15.9*	6.4-6.8	11.2

* For pH 10.0, alkalinity 10 p.p.m. only.

values. This, however, is not surprising when the nature of the carbon dioxide determination and the differences in individual technique are considered. A clearer picture is obtained when comparisons are made on the basis of careful analytical studies, such as those of Wagner and Enslow (15), which were made in order to check a similar graph based on the work of Tillmans.[5] Table 3 contains a comparison between a few of Wagner and Enslow's determinations, selected at random, and the carbon dioxide content of the samples as

[5] De Martini's equation for carbon dioxide differs from that of Wagner and Enslow only in the use of a more recent value of the ionization constant K_1, and in the introduction of correction terms for the hydrogen, hydroxyl and normal carbonate ions present.

obtained from fig. 1. The discrepancies between the two values are, in general, not greater than the probable experimental error of the carbon dioxide determination.

In the case of alkaline waters, containing bicarbonate and normal carbonate, or normal carbonate and hydroxide alkalinity, few satisfactory analyses seem to be available in the literature, the amounts of normal carbonate and hydroxide being usually too small to furnish

TABLE 3

Comparison of Determined and Indicated Values

SAMPLE	pH	TOTAL ALK.	CO_2	
			Determined	From Fig. 1
Alexandria, Raw	6.8	11.0	4.0	3.4
Coagulated	6.6	10.0	6.0	5.0
Filtered	6.45	10.0	7.0	6.7
Clinchfield, Raw	6.55	80.0	44.0	43.5
Coagulated	6.60	70.0	36.0	34.2
Filtered	6.40	60.0	46.0	46.3
Danville, Raw	7.55	22.0	1.5	1.2
Coagulated	6.45	10.0	7.0	6.8
Filtered	6.65	12.0	5.0	5.1
Franklin, Raw	7.0	15.0	3.0	2.8
Coagulated	6.0	3.0	7.0	5.7
Filtered	6.0	3.0	7.0	5.7
Petersburg, Raw	7.3	31.0	3.0	3.0
Coagulated	6.7	22.0	9.0	8.5
Filtered	6.7	23.0	8.0	8.8
Norfolk, Raw	6.95	25.0	4.0	5.3
Coagulated	6.6	21.0	9.0	10.2
Filtered	6.6	20.0	8.0	9.7
Richmond, Raw	7.35	23.0	4.0	2.0
Coagulated	6.5	16.0	8.0	9.8
Scottsville, Raw	7.35	33.5	1.5	2.8

a reliable check. Synthetic waters containing these ions were therefore made up and analyzed both by the phenolphthalein-methyl orange titration method, and by potentiometric titration, using the quinhydrone electrode for sample number one, and the glass electrode for the remainder of the samples. Table 4 shows a comparison between the analytical results, and those obtained from the diagrams.

The data of table 4 show substantial agreement between the determined values of the three forms of alkalinity and those obtained from the diagrams, except in the case of samples 7, 8 and 9, which have relatively high hydroxide alkalinities. Samples 1 and 2 clearly illustrate the tendency of the phenolphthalein-methyl orange titration to overestimate the normal carbonate alkalinity when its value is small. In these two samples there is better agreement between the

TABLE 4

Comparison of Analytical and Diagram Results

Sample Number	1	2	3	4	5	6	7	8	9
pH	8.50	8.75	9.60	9.78	9.80	9.90	10.20	10.75	11.05
Total Alkalinity									
By Methyl Orange	48.0	19.6	50.0	74.0	33.8	190.5	47.8	51.8	80.0
By Electrode	50.0	19.0	48.0	72.0	31.3	188.8	45.0	50.0	79.0
Bicarbonate Alkalinity									
By Phenol. and M.O.	40.4	16.3	33.2	41.0	17.5	110	13.6	—	—
By Electrode	47.0	17.5	33.0	40.0	15.8	105.8	10.0	—	—
From Fig. 2	48.0	17.5	32.0	41.0	16.5	98.0	13.5	3	2
							13.6*	3.3*	2.2*
Normal Carbonate Alkalinity									
By Phenol. and M.O.	7.6	3.3	16.8	33.0	16.3	80.5	34.2	38.5	42.0
By Electrode	3.0	1.5	15.0	32.0	15.5	83.0	35.0	33.0	38.0
From Fig. 3, 4	2.0	1.3	14.5	28.0	12.0	87.0	23.8	19.0	21.0
							24.6*	20.9*	28.7*
Hydroxide Alkalinity									
By Phenol. and M.O.	—	—	—	—	—	—	—	13.3	38.0
By Electrode	—	—	—	—	—	—	—	17.0	41.0
From Fig. 5	—	0.3	2.0	3.0	3.0	4.0	7.5	28.0	56.0
							6.9*	24.2*	49.0*

* Corrected for temperature and ionic strength of water.

values obtained from the diagrams and by potentiometric titration. The diagrams may therefore be considered satisfactory for waters containing normal carbonate and bicarbonate alkalinity.

For waters containing normal carbonate and hydroxide alkalinity, such as samples 7, 8, and 9, it is evident that either the equations which are the basis of the diagrams overestimate the hydroxide content, or that the titration methods underestimate it. There are two

reasons for believing the titration methods to be in error. The first is that the equation by which the hydroxide content is determined from the pH is well established by physio-chemical research. The second is that the computations by which the hydroxide and normal carbonate content are determined from the phenolphthalein and methyl-orange end-points or from the equivalent potentiometric end-points are based on assumptions which are essentially correct for concentrated solutions, but which cannot be relied upon in dilute solutions. It will be noted that sample 9, which contains a higher total and hydroxide alkalinity than sample 8, shows a relatively better agreement between the hydroxyl content as determined by titration and that obtained from fig. 5.

Effect of Temperature

The diagrams are based on the values of the constants K_1, K_2, and K_w for a temperature of 25°C., and are therefore strictly accurate only for water at that temperature. It can be deduced from figures given by MacInnes and Belcher (reference 14, pp. 2639, 2645), that each degree centigrade increase in the temperature of the water above 25°C. increases the value of K_1 by 0.25 per cent, and the value of K_2 by 0.58 per cent. As a first approximation, these correction factors may be assumed to hold also for temperatures below 25°C. The changes are small, and may be safely neglected for most waters. The constant K_w changes with temperature to a much greater extent. Its value is 1×10^{-14} at 25°C., 0.593×10^{-14} at 18°C., and 0.116×10^{-14} at 0°C. However, K_w exerts a negligible effect on the equations for carbon dioxide, bicarbonate and normal carbonate at all pH values below 10.0, and therefore the temperature corrections may be ignored for most waters. The temperature corrections are also generally neutralized at least in part by corrections for the influence of dissolved salts on the values of the constants, as will presently be shown. It should be emphasized that the significant temperature is the temperature of the sample used to determine the pH of the water.

Effect of Concentration of Dissolved Salts

The values of the constants K_1, K_2, and K_w are also affected by the presence in the water of other salts, becoming greater as the total concentration of salts in the water increases. The reason for the increase lies in the diminution of the so-called "activity" of the vari-

ous ions as the total salt concentration increases. The values of the constants depend on the "ionic strength" of the water, which is defined as "one-half the sum of the concentrations times the square of the valences of all ions present in the water." This quantity is difficult to determine, but Langelier (reference 13, p. 1506) has devised a simple method for estimating its value for any water. According to Langelier:

Ionic Strength $= \mu = 0.000025 \times$ p.p.m. dissolved solids.

Equations for correcting the values of the constants for salt concentration may now be considered. In all these equations the terms K will represent the values of the constants at zero ionic strength. These are the values commonly given in handbooks, and used in the construction of the diagrams. The terms K′ will represent the values of the constants at any other ionic strength, μ.

For K_1, MacInnes and Belcher (ref. 14, p. 2637) give the following equation:

$$\log. K_1' - \log. K_1 = 0.119\ \mu$$

Calculation will show that even in a water containing 800 p.p.m. dissolved solids, K_1' exceeds K_1 by only 0.52 per cent. All corrections may therefore be neglected for the carbon dioxide diagram.

For K_2, according to MacInnes and Belcher (ibid, p. 2643):

$$\log. K_2' - \log. K_2 = 0.382 \sqrt{\mu}$$

The correction in this case is larger, K_2' exceeding K_2 by 4.5 per cent at 100 p.p.m. dissolved solids, and by 13.2 per cent at 800 p.p.m. dissolved solids.

For K_w the best information available is that given by Kolthoff and Rosenblum (17).

$$\log. K_w' - \log. K_w = 0.50 \sqrt{\mu} - 0.58\ \mu$$

In this case K_w' exceeds K_w by 5.8 per cent at 100 p.p.m. dissolved solids, and by 15.0 per cent at 800 p.p.m. dissolved solids.

It will be noted that a temperature lower than 25°C. calls for values of the constants which are lower than those used in constructing the diagrams, whereas a dissolved solids concentration greater than zero calls for higher values of the constants. Most waters have temperatures below 25°C., and all have dissolved solids contents greater than zero, and therefore the two correction factors tend to neutralize each other. Furthermore, the influence of the large correction factors of

K_w becomes great only at pH values above 10.0. The net result of these opposing tendencies may be stated as follows:

> For waters having temperatures from 15–25°C., dissolved solids concentrations of 500 p.p.m. or less, and pH values below 10.0, all corrections may be neglected, and the diagrams may be used in the form given in this paper.

For waters outside these limits, the values of the constants may be corrected for temperature and salt concentration, and the corrected values substituted directly in the equations. Table 4 shows, in samples 7, 8, 9, a comparison between values of bicarbonate, normal carbonate and hydroxide obtained directly from the diagrams, and the corresponding values obtained by correcting for the temperature (22°C.) and the ionic strength of the respective samples. The difference between uncorrected and corrected values is small at pH 10.2, but becomes appreciable at pH 11.0.

Summary and Conclusion

The carbon dioxide, bicarbonate, normal carbonate and hydroxide content of natural and treated waters may be calculated from the pH and total alkalinity of these waters by means of equations based on physical chemistry. These equations may be plotted in the form of diagrams, from which the parts per million of these substances present in the waters may be read directly. The limitations of the equations and diagrams are discussed. The diagrams as published in this paper are suitable for use over the range of temperatures and dissolved solids concentrations most frequently found in practice. For other ranges of temperatures and solids concentrations, either the equations may be used directly, or similar diagrams may be constructed, by applying the appropriate corrections to the values of the constants K_1, K_2, and K_w.

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Factors in Coagulation

By Burton W. Graham

WE GENERALLY look upon coagulation as one of the simplest steps involved in the manufacture of a finished water whether for domestic or industrial use. It is quite true that the general control of coagulation is very easily watched and governed because of certain rules that have been established by past investigators and past experience. There are certain ranges of pH over which various coagulants will form insoluble compounds called "floc," and the utilization of this fact alone has contributed in no little measure to making coagulation easy to control.

Observation of the type of floc and its size and ability to settle are simple rules utilized in some plants where chemical equipment is not available. An experienced operator may adapt these points quite well to hitting approximately the best range of coagulation, but he is generally behind time if the character of the raw water changes since he must wait until an undesirable "floc" at the end of the mixing basin shows him that the correct dosage was not applied. So simple are these familiar general coagulation guides that we sometimes forget to consider the more specialized work that good coagulation is able to do and we neglect even attempting to utilize the extra plant efficiency which may be obtained by controlling coagulation to more exact conditions.

The coagulating basin is the heart of the plant. Just as a weakening of the heart action of the human system causes improper functioning of the system, so does the effect of poor coagulation vibrate throughout the water plant. In many plants the source of raw water is such that its particular characteristics change from time to time, in some instances from day to day, and where the raw water is drawn

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from some rivers its characteristics may change hourly. The slightest negligence in respect to a continued vigilance toward the optimum coagulating conditions may allow the color and the turbidity to arise above the maximum point which can be allowed to insure no complaints from the consumers.

There is no one factor alone which can measure the results obtained in coagulation, nor can utilization of any group of factors bring about a revolutionary change, but a thorough understanding of the basic factors concerned enables us to effect far more efficient coagulation and ease plant operation.

Relationship of Alkalinity or Acidity and pH

The formation of the floc depends upon certain fundamental chemical laws. There must be a minimum coagulating ion concentration which varies with the coagulant used and there must be present in the raw water an equivalent alkalinity or acidity for complete reaction for the formation of the hydrous metallic oxide. If these are not naturally present in the raw water, an artificial alkalinity or acidity must be added in sufficient quantities to allow reaction with the coagulant ions and an additional quantity necessary to stabilize the effluent water with respect to corrosion and after precipitation in the mains.

There is a broad relationship between the alkalinity or the acidity and the active hydrogen ion concentration of waters generally denoted as the pH value. The buffering effect of various salts present and that of water itself has a pronounced influence on this relationship so that the measurement of pH does not divulge all of the important factors concerned in the application of coagulants. pH values have indeed been useful in a general way to help control coagulation since each type of floc is relatively insoluble over a certain wide pH range and more completely insoluble at a narrow point on the range where the most complete precipitation of the coagulant ion occurs with the least residual coagulant in the filtered water. Since the pH range of coagulation in raw water is influenced by the type and variety of ions present, we must treat every water as an individual problem and ascertain the optimum conditions in each. So pronounced is this fact that in numerous sections of the country the acidity or alkalinity of the water and not the pH is the important point to consider.

The control of temperature when making jar tests to that of the conditions in the mixing and coagulating basins is of value. Gen-

erally we hope to apply such miniature tests as closely to plant condition as possible so they will have definite meaning to us. Temperatures below 40° F. and above 70° F. usually require more coagulant than the intermediate range. A rise in temperature materially speeds up the reaction and reduces dosage required due to the increased activity of the reacting and influencing ions. Low temperatures produce a slow, sluggish and a more incomplete reaction requiring larger dosages to obtain the desired results. It is important to bear this fact in mind especially in the section of the country where seasonal variations cause severe changes in the temperature of the water.

It is of fundamental importance that the chemical be thoroughly mixed with the water and it is highly desirable that the chemicals be given sufficient time to react before going to the settling basins. Usually 30 minutes retention is sufficient. The engineering design of plants takes this into consideration and it is generally not the problem of the plant operator. Jar tests will have little meaning unless stirring conditions match those of the plant closely

Effect of Stirring and Mixing

Proper mixing and flocculation go a long way in building up a heavy, well defined floc, and in keeping the floc particles, while forming, in contact with the material which it is possible for them to remove. Insufficient time and speed of mixing will cause a larger dosage to be required, thereby increasing cost of coagulants.

There are many different coagulants on the market today, each perhaps with some point of value pointing toward its use. Aluminum sulfate is most extensively used in the water works field; but various iron salts, bentonite, titanium salts, sodium aluminate, and other compounds have been found to be advantageous in some instances. The choice of a coagulant depends on the economic aspects which usually are developed from the following considerations:

1. Alkalinity or acidity and pH
2. Mineral content
3. Probable taste and odor conditions
4. Turbidity and color problems
5. Possible clear or turbid raw water to be treated
6. Removal of industrial wastes

Alkalinity, acidity, and pH of the raw water are of prime importance in the selection of a coagulant. Every effort possible should

be made to utilize the natural characteristics of the raw water and select the coagulant which is suited for a particular type of water rather than make the water by artificial means suit a coagulant which is arbitrarily selected. A water of high pH and alkalinity should be treated with the coagulant most suited for that range unless the particular problem of coagulation is involved with removal of material at a lower pH range. Likewise a low pH and low alkalinity water might well be coagulated by a chemical more particularly useful at that point. There is no need to break down artificially an alkalinity or to build one up unless other factors than coagulation demand it. Such a procedure is only additional expense.

Mineral content and hardness further affect the selection of the most economical and best coagulant. Many natural waters contain an abundant supply of coagulating ions, sometimes in sufficient quantities to coagulate the waters if the conditions can be transformed suitably for their reaction. If only a portion of the necessary quantity of coagulating ions is present in a natural water, a small additional quantity of the same would probably prove to be more economical than the use of an entirely different coagulant. Softening needs also enter into the economies of coagulation.

Activated Carbon in a Coagulant

Taste and odor problems are indeed worthy of consideration when selecting coagulants. One coagulant has been developed to combat these conditions within the coagulating basin all the way through the plant to the filters.

An activated carbon coagulant does both the job of coagulating more efficiently and at the same time removing tastes and odors. By its use the plant becomes completely permeated with the activated carbon which sweetens the entire plant, removes moderate tastes and odors, stabilizes sludge, and keeps the plant in a condition whereby it is ready to meet more easily the excessive taste and odor problems when they arise.

Turbidity and color problems should affect the choice of the substance used for their removal. Since the colloidal turbidity and the color bodies usually carry a negative electrical charge, it is well to select a coagulant whose particles during formation bear an opposite electrical charge in the coagulating range to assist in the precipitation and absorption of the turbidity and color. Further it is sometimes necessary to drop the pH very low to remove some coloring matter

and the coagulant involved must have the characteristics enabling it to work in the low pH range necessary. It should be one containing the highest acid to coagulant ion ratio possible so unnecessarily large quantities would not be needed to reduce the pH. In some cases an addition of a small amount of acid is desirable, though in many instances conditions make its use uneconomical.

Raw waters which carry almost no turbidity as a general rule are most difficult to coagulate. An artificial turbidity is usually desirable and helpful since it furnishes material on which the metallic hydroxide may begin to floc. Generally the coagulant dosage is reduced because the artificial turbidity similar to the natural turbidity bears an electrical charge which more completely satisfies the physical chemical laws of colloidal precipitation. A coagulant which includes both the feature of adding artificial turbidity and at the same time contains activated carbon is of special value in such waters.

Removal of industrial wastes from a water supply often proves troublesome and certain coagulants are more adapted to this problem than others. Certainly the source of industrial pollution should be removed but sometimes it is not possible. Removal of dyes may require almost any pH range for best control. Organic material may require heavy dosages of chlorine for oxidation and a coagulant suitable for use with chlorine may prove an advantage or an activated carbon coagulant may aid in dechlorinating and in the removal of soluble organic materials.

Factors in Coagulation Control

For a more complete discussion of the various factors contributing to efficient coagulation it would be best for us to get a cross-sectional view of what actually happens in the mixing and coagulating basins and study these points in respect to their effect on the entire plant.

As soon as the coagulant is dissolved in the water a chemical reaction begins to take place between the alkalinity or the acidity of the water and the metallic ion dissociated from the coagulant. This reaction is called hydrolysis and its speed is dependent upon the hydrogen ion concentration or acidity or alkalinity of the water. Hydrolysis results in the adjustment of pH and the formation of many insoluble microcrystals of the metallic hydrate which are soluble on both the more alkaline and the more acid side of its pH coagulating range. These microcrystals gradually grow during agitation to

colloidal particles which assume an electrical charge by absorption of ions around them. This is a most important phenomenon since it is this electrical charge alone which enables the coagulant to clarify and decolorize waters so effectively.

Generally color and colloidal turbidity possess a negative electrical charge which on contact with the colloidal coagulating material of opposite charge becomes electrically neutralized according to physical colloidal chemical laws. This phenomenon is instantaneous and yet the entire job of the coagulant is done here. Color, turbidity, and other undesirable substances such as colloidal organic particles are neutralized and absorbed in this action. Here also colloidal silica play its part in improving coagulation. The reduced dosages of activated alum, in many instances, indicate the effect of a colloidal silica as a factor in improved coagulation control.

Continued agitation and flocculation are simply means of building up the size of these coagulated particles to sufficient size and weight to allow them to settle out in the settling basins and remove the load from the filter beds. It is desirable, however, to allow a small portion to get to the filters to build up a mat through which to filter.

Now the importance of applying the correct coagulant dosage can be readily seen and the effect of improper coagulation can easily be visualized. The more we allow the dosage to vary from the range of optimum conditions, the more soluble does the hydrous metallic oxide become. Only a small part of the material is actually insoluble and an equilibrium is set up between the soluble, the colloidal, and the coagulated material. In this form a partially hydrolized coagulant is carried with the water to the filters. Very little of this type of floc settles and the job of producing clear water falls to the filters.

The coagulated particles are small and incompletely formed. They penetrate quite deeply into the filter sand and smaller particles penetrate farther until the openings between the sand grains are closed and the filters require washing after only a short run. Further, the water which has filtered through has carried with it colloidal material and a high soluble coagulant residual. The wash water in such cases becomes an expensive item, whereas under proper coagulation a blanket of well defined floc would form over the filter sand, long filter runs would be obtained, and wash water cost would be low.

Should taste and odor problems require the application of activated carbon on the filters, shortening of filter runs by improper coagulation would be even much more an expensive item. The filters would require washing in many instances before the carbon

had become deactivated to an economical point for discard and this value would be washed away. In instances where conditions bring about continually short filter runs, it is advantageous to use an activated carbon coagulant and thus control removal of tastes and odors in the coagulation basin. In this manner the full value of the activated carbon is obtained. In general we should aim at coagulating with the smallest amount of chemical which will produce the desired water and still give a long filter run. Experiments should be made continually until the most economical combination is obtained between coagulant dosages and wash water costs.

Where water is being softened with lime soda process along with coagulation the same points are of value. Since lime is far cheaper than soda ash, we should make it do as much work as possible in producing a balanced water and use only the soda ash required to complete the job. This economic balance is simply a mathematical calculation concerning the mineral content, alkalinity, carbon dioxide, and incrustant and total hardness reduction to the figure suitable for domestic supply.

There is no doubt that coagulation is turning to more specialization than heretofore and water works men are realizing the value and accepting more and more the specialized coagulants in the field. It is too optimistic, however, to visualize any one coagulant so specialized as to treat more economically different types of water—waters with high alkalinity and high pH, low alkalinity and low pH, and moderate alkalinity and neutral pH, as well as waters with taste and odor problems. It is toward this end that much research work is devoted.

Conclusions

Coagulation is so easy to control that we sometimes overlook important factors.

Perfect functioning of the entire plant depends on proper coagulation control.

Alkalinity, acidity, buffer salts, and pH influence coagulation.

Stirring, mixing, and temperature have definite effect on floc formation.

Colloidal physical chemical laws are involved in the process of coagulation.

Chemical dosages should be balanced with length of filter runs.

Selection of a coagulant involves study from the standpoint of economy of what can be done with each coagulant and what is to be required.

Quality Throughout the System

By George E. Harrington

THE quality of a water for a public supply should be such (1) that it shall contain no organisms which cause disease; (2) that it shall be sparkling, clear and colorless; (3) that it shall be good tasting, free of odors, and preferably cool; (4) that it be reasonably soft; (5) that it be neither scale forming nor corrosive; and (6) that it be free from objectionable gas, such as hydrogen sulphide, and objectionable minerals, such as iron and manganese.

The progress in water treatment and filtration in the past few years gives assurance that the ideal water is within reach of every municipality. Good quality water is doubly assured if the filtration plants are under the control of competent and experienced men well trained in the field of sanitation.

Assuming that all care has been taken to provide a good quality water at the plant effluent, this does not necessarily mean that the same good quality will exist throughout the entire distribution system. There are certain factors that may alter this quality, namely: dead-end mains, causing high bacteria count, aftergrowths, tastes and odors; lowering of pH, causing corrosion; and, most serious of all, cross connections, which may contaminate the water supply system. It is essential then to exert the utmost care and effort to remove these causes from the distribution system.

In looking over what has been reported and written, you will find that nearly every man in charge of a water supply system has experienced some of these troubles and has tried different methods to remedy them. The city of Washington, D. C., has experienced its share from time to time and this paper will describe the procedure followed to maintain a good quality of water not only at the effluent, but throughout the distribution system as well.

A paper presented at the Four States Section meeting, Washington, D. C., October 6, 1938, by George E. Harrington, Asst. Chemist, Dalecarlia Filter Plant, Washington, D. C.

First a few words about the water supply system of Washington. Unlike most other cities, the water supply system of Washington is under the control of both the federal government, that is the United States Engineer Office, and the district government. There is, however, always good coöperation between these two branches of government at all times.

The federal government has under its control the conduits that supply the raw water to the large storage reservoirs, two filtration plants, namely, the Dalecarlia Rapid Sand Plant and the McMillan Slow Sand Plant, the chemical and bacteriological laboratories and the pumping stations.

The laboratory has direct control of all chemical treatment at both plants and is entirely responsible for the quality of the water of the effluent of plants as well as the quality of the water in the distribution system. The district has control of the mains, both maintenance and laying of new ones, installing meters, and collecting water rents. The district government also maintains a public health laboratory where are run bacteriological tests on the city water.

The source of supply for the city is the Potomac River. This water is free from tastes and odors most of the time. The water is treated at the Dalecarlia Plant in the usual manner: coagulation with alum, chloramine treatment before filtration, chlorination after filtration, and the final adjustment of pH with lime.

To be sure that there is sufficient residual chlorine in the water as it leaves the plant, the operators are required to make residual chlorine tests every fifteen minutes. The exact residual necessary is set by the laboratory. From past experience it has been found that a lower residual can be carried at the rapid sand plant during the winter than in the summer. The reverse is true at the slow sand plant. In the summer the residual carried at the plant is between 0.30 to 0.35 p.p.m., whereas 0.15 to 0.20 p.p.m. is sufficient in the winter.

The pH of the final effluent is maintained by means of the Leeds & Northrup pH recorder, and is usually carried between 7.6 to 8.0. The carbon dioxide content of the water as it leaves the plant is kept as nearly as possible between 1.0 and 2.0 p.p.m., and this fact has a bearing on the final adjustment of the pH.

To be sure that the water, as it leaves the plant, is always of good quality both bacteriological and chemical samples are collected every four hours throughout the day of both the filtered and the chlorinated

supplies. The bacteriological samples are tested for the coliform group as well as the plate count. The chemical samples are tested for pH, carbon dioxide hardness, dissolved oxygen and alkalinity. From both of these tests the exact quality of the water as it leaves the plant is known.

The water thus filtered and prepared is pumped from the covered filtered water reservoir into three high service reservoirs, all of which are covered. These reservoirs are located in different sections of the city and supply the respective areas by gravity. The water in these reservoirs is tested daily both bacteriologically and chemically, and if at any time it happens to show the presence of coliform, the reservoir in question is immediately treated with calcium hypochlorite.

No Contamination from Faucets

Throughout the high service areas in the city, sampling points have been established. Twice a week samples are collected and taken to the laboratory for bacteriological and chemical tests. In collecting these samples a procedure is followed which eliminates any doubt of contamination from faucets. All faucets are thoroughly flamed before samples are collected.

The McMillan Slow Sand Plant supplies the gravity area of the city. In this area the same procedure of collecting samples is followed as in the high service area. Systematic sampling of both areas assures a good check on the quality of the water. As a further check on the water, the District of Columbia Health Department laboratory makes similar tests, thereby giving a double check on the water.

In the distribution system of Washington, as well as in other cities, there are dead-end mains. To eliminate the possibility of taste and odors a systematic system of flushing is carried out. These particular spots have been mapped out and are flushed at least once a week.

New mains are often the cause of contamination to the water system, and before any new mains are placed in service they are thoroughly flushed, refilled and chlorinated heavily with calcium hypochorite and allowed to stand at least twenty-four hours. Then they are drained and thoroughly flushed until free from residual chlorine. Bacteriological tests are then made to determine whether or not the water is free from the coliform group before the main is put into operation. This method has proven satisfactory.

Cross connections between potable water and a privately owned supply can at times cause untold damage to a good water system. These connections are usually made for added fire protection, or utilization of a private well supply. Whenever a cross connection is found, it is immediately reported to the District of Columbia Plumbing Inspector and extra inspection is made of the water supply of that particular area. Chemical tests of the water in these cases are just as important as the bacteriological tests.

A case in Washington, D. C. a few years ago was detected not alone by the bacteriological test but mainly by the chemical test. The bacteriological tests showed the presence of the coliform group but the chemical test showed the water to be entirely different from the city water and from these chemical tests the cross connection was traced to a well which had been cross-connected to the city supply.

Washington maintains a good quality of water not only at the effluent of the plant but also throughout its entire distribution system by following the above described procedure, that is, through systematic sampling, both at the plant, and in the distribution system; flushing dead-end mains regularly; and chlorinating of new mains before putting them into operation.

Incrustation from Excess of Calcium Carbonate

In other cities we find different methods used to maintain good quality of water throughout their respective distribution systems. To eliminate the corrosion problem to both iron or zinc, some increase the dosage of lime to form a protective coating on the interior of the mains. An excess of calcium bicarbonate must be watched, however, because the volume of incrustation can be such that it decreases the rate of flow through mains.

For taste and odors the chloramine treatment is resorted to, to increase the residual chlorine and carry it further in the distribution systems. Some resort to chlorinating mains directly either with liquid chlorine or with calcium hypochlorite. In other cities, we find the use of bleeders to eliminate dead-end troubles.

All of these methods and probably others are used from time to time and it is necessary for the individual to figure out the best method to help him solve his problems.

Discussion by *M. H. Coblentz.* * In any discussion of this subject the chemical, bacteriological and microscopical quality of the water, before it enters the distribution system, is of vital importance.

Perhaps the strictly physical effects most frequently responsible for the appearance of turbid water at the consumers' taps after it has entered the distribution system clear and sparkling, result from flushing, lack of flushing or fluctuations in water pressure, emergency repairs to broken mains, rainfall and wind effects on open service reservoirs that are not lined or other similar disturbances to uniform movement of the water through the system. Secondary precipitation and red water are interrelated and may be due to improper treatment at the water plant. Cross connections in a physical way may affect the chemical and bacteriological quality of the water in any distribution system and are potential hazards.

More often than not, chemical changes within distribution systems take place through the agency of bacteria and micro-organisms other than bacteria, some of which are resistant to the usual disinfecting agents. Much of this microscopic life originates in open service reservoirs, where, obviously, it is more difficult to control than at a filtration plant. In the absence of open storage on the distribution system the responsibility of excluding these agencies rests entirely with the superintendent of the treatment works.

The control of the chemical and bacteriological quality at the filtration plant is relatively well understood and effective practices and laboratory control methods are pretty well established. Many, however, believe that such procedures may need to be extended in order to supply adequate protection to the public against certain types of gastro-intestinal ailments frequently occurring in many communities. It is believed that some of these outbreaks at least have been due to some irritant of organic or mineral origin. It has been suggested that toxins liberated by blue green algae may be responsible for such an effect and that various pollens and windborne dusts falling into reservoirs may act as irritants on susceptible or allergic persons. This field certainly deserves some study. On the other hand, the control, at the treatment plant or in open services, of numerous kinds of micro-organisms other than bacteria and bacteria other than those belonging to the coliform group

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(many of which have been found to grow profusely in distribution systems in anaerobic as well as aerobic environment) is not nearly so well understood and consequently effective procedures for their elimination have not been so well developed.

The studies of Reddick and Linderman, published in the Journal of the New England Water Works Association (vol. 46, pp. 146–169, 1932) indicate that tuberculation is due to biological action and that *Crenothrix* and bacteria other than the well known iron bacteria actually attack an iron pipe by producing acids at the point where they have attached themselves. Iron is dissolved from the pipe by the acid and the organism in its process of metabolism removes the iron from solution and deposits it as ferric hydroxide. *Crenothrix* occurs chiefly in ground water rich in organic matter, iron compounds and carbonic acid and deficient in oxygen; and growth is favored by darkness. Growth and decay cause such troubles in service reservoirs and mains as foul tastes and odors, red water and clogging of pipes. Furthermore, since dead and decaying *Crenothrix* growths are known to provide an excellent medium for bacterial growth, it is not surprising to find that aftergrowths of gas-forming bacteria in distribution systems are usually accompanied by *Crenothrix* or algae growths.

Chloramines prevent red water in dead ends by destroying the *Crenothrix* or other iron bacteria which naturally seed heavily and accumulate in such places. There are a number of ways of applying chlorine treatment for removing tastes and odors at the treatment plant and for preventing the deterioration of water within the distribution system. Each supply has its individual point and method of application which is most effective and this should be accurately determined.

In attacking the difficult problem of deterioration of water quality within the distribution system, it seems that the place to start is at the treatment works. Many treated waters that appear to be excellent in physical quality, free from coliform organisms and adjusted in pH value and alkalinity to prevent corrosion from the purely chemical standpoint, carry seeding micro-organisms and organic matter from time to time into the distribution system where their activities are concentrated in low draft sections and dead ends. Dead ends are something that should be restricted to an absolute minimum in any water works distributing system. The growing use of duplicate mains on each side of a street should make the number of dead ends

between pressure districts less necessary. The practice of locating fire plugs on dead ends as effective bleeders for mains is desirable for flushing pipe lines, but not so satisfactory from the standpoint of fire protection.

I am reasonably certain that improvements in coagulation, probably best accomplished by a better understanding of the rôle of chemical mixing in preparing the water for the filter, are capable of reducing the number of micro-organisms and their organic food material leaving the filter.

Open service reservoirs should preferably be avoided, but certainly rigidly controlled microscopically and bacteriologically.

There should be a well established system of flushing based upon a thorough knowledge of the distribution system and the relative efficiency of all parts thereof in delivering to the consumers the best quality of water. Nothing, probably, is more helpful than complete records, not only of the location of mains, hydrants, valves, etc., but of complaints and other evidences of poor quality of water, when, where, why and how. In most cases certain fixed times for flushing, such as every few weeks or few months, are not preferable for every water system, nor for every dead end in the same system. In almost every system the quantities of oxygen, carbon dioxide and organic matter vary so much with the season and with the several sources of supply that only experience in the individual case can be used as a safe criterion. Flushing should be properly done. It is not merely a matter of draining water from fire plugs. In general the flushing of a distribution system should begin at the source of supply or treatment works and proceed to the ends. There should be strategic manipulation of valves to segregate properly individual sections for separate flushing; velocities should be controlled properly; and frequently, reversing the flow is desirable to clean some sections.

The management of the distribution system should be at least shared, if not entirely supervised, by the superintendent of the treatment works and his chemical, bacteriological and microscopical control should cover the distribution system as well as the treatment plant. Adequate laboratory facilities should be provided and laboratory and plant operating records should be complete and frequently correlated. The necessity of highly trained, conscientious, reliable and well paid water supply superintendents is obvious.

Regulating Water Treatment in Buildings

By John L. Rice, M.D.

FOR several years, the New York City Department of Health and the Department of Water Supply, Gas and Electricity have been studying the question of regulating the addition of chemicals to water supply systems in buildings.

Many buildings in the city have been arranging with service agencies to treat the water in their buildings, to reduce corrosion of the piping systems. It was felt by the city departments that this work should be rigidly regulated, as there were definite possibilities of mistakes or accidents occurring, which might affect the quality or safety of the water supply in the buildings, or even in the city mains outside.

Following a number of conferences with technical committees, representatives of the firms engaged in this business, and representatives of the Merchants' Association, a set of regulations was drawn up. The Board of Health, at its recent meeting, enacted a new Section, 170, to control this problem.

The chief features of this section are that every firm engaged in this business must obtain a permit from the Department of Health, that such permits are to be given only where fully qualified chemical engineers are in responsible charge of all operations in connection with water treatment in buildings. A report is to be submitted to the Department of Health within twenty-four hours after installation or servicing of any new locations. Eight chemical compounds have been specified which alone can be added to the water supply, and within maximum limits that are given.

The regulations prohibit the addition of chemicals to water supply in buildings by janitors, superintendents, or any persons other than

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Record of Board action transmitted by John L. Rice, M.D., Commissioner, Department of Health, New York City.

responsible employees of licensed firms. Chemicals are to be added by devices that must be approved by the Department of Health.

The resolution and regulations are as follows:

Resolution

Herewith are presented resolutions of the Board of Health of the City of New York, adopting new Section 170 and regulations, for control of the addition of chemicals to water supply in buildings.

RESOLVED: That article 9, the Sanitary Code, be amended by adding thereto a new section to be numbered "170," to read as follows:—

Section 170. Addition of chemicals to water supply in buildings regulated; permit required.

(a) No person shall in the City of New York add, or engage in or by a sign or otherwise advertise or hold himself out as engaged in the business of adding, any chemical or other substance to the water supply within a building without a permit therefor from the Commissioner of Health. Such addition of chemicals shall be for anti-corrosion or anti-scaling purposes only, and shall be performed in conformity with the terms and conditions of said permit and the regulations of the Board of Health. No owner, lessee, occupant, tenant, or other person in charge of a building shall cause, permit, allow or suffer any chemical or other substance to be added to the water supply in such building which water supply is subsequently furnished to any guest, customer, occupant, tenant or other person for domestic use or human consumption, unless such addition or treatment is performed by the holder of a permit from the Commissioner of Health and in accordance with the regulations of the Board of Health. The provisions of this section shall not apply to the treatment of water for industrial purposes, for swimming pools, for air conditioning systems, or for any use which does not include human consumption, but in all such cases proper precaution shall be taken to preclude the possibility that the treated water may come into contact with or contaminate the potable water supply distribution system of the building and provisions satisfactory to the Department of Water Supply, Gas and Electricity shall be made to preclude the possibility that the treated water may come into contact with or contaminate the public water supply.

(b) Only the following chemicals or mixtures thereof may be added to the water supply in a building: sodium silicates, sodium carbonate, sodium bicarbonate, sodium hydroxide, sodium phos-

phates, calcium carbonate, calcium bicarbonate, and calcium hydroxide. None of these chemicals shall be added in such manner as to increase the total alkalinity, total hardness or total silica content of the water by more than 50 parts per million as determined by the methods of water analysis contained in the latest edition of "Standard Methods of Water Analysis" approved by the American Public Health Association and the American Water Works Association.

(c) Addition of chemicals to the water supply in a building for anti-corrosion or anti-scaling purposes shall only be made by means of an approved mechanical device or apparatus designed and constructed to regulate the chemical dosage to conform with the provisions of this section. Such mechanical devices or apparatus shall be examined and if found satisfactory shall be approved by the Commissioner of Health. The Commissioner may appoint an Advisory Committee composed of representatives from the Health Department, Department of Water Supply, Gas and Electricity, the Association of Consulting Chemists and Chemical Engineers, the New York Section of the American Chemical Society, the New York Section of the American Institute of Chemical Engineers, and the American Water Works Association, to assist him in passing upon any such mechanical device or apparatus.

(d) A water supply system in any building that includes a mechanical device or apparatus for chemical anti-corrosion or anti-scaling treatment shall be equipped with protective means to prevent backflow or siphonage of treated water into the public water supply system. Such protective means shall be approved by the Department of Water Supply, Gas and Electricity.

(e) This section shall become effective April 1, 1939.

(As adopted by the Board of Health, December 12, 1938)

Regulations Under Section 170

RESOLVED: That "Regulations Governing the Addition of Chemicals to Water Supply in Buildings for Anti-corrosion or Anti-scaling Purposes," and relating to Section 170 of the Sanitary Code, be and they are hereby adopted to read as follows:

Regulation 1. Application for permit.—An application for a permit to engage in the business of adding chemicals to the water supply in a building for anti-corrosion or anti-scaling purposes, shall be made to the Commissioner of Health on forms furnished for such purpose by the Department of Health.

Regulation 2. Required qualifications of applicant.—A permit to

add chemicals to the water supply in buildings for anti-corrosion or anti-scaling purposes, shall be issued only to persons holding a chemical degree or a degree in chemical or sanitary engineering, from a college or university approved by the Regents of the University of the State of New York, and having at least 5 years' experience in some work closely related to the chemistry of water. If the applicant for a permit is a partnership, at least one member thereof, or if a corporation, at least one officer thereof, must possess the aforesaid qualifications. In addition thereto such partner or officer must be engaged for full time in said partnership or corporation respectively, and have direct charge and supervision over all installations and activities in relation to the addition of chemicals to a water supply in a building. Where an applicant engaged in the business of adding chemicals to water supply in buildings for a period of five years or more prior to the date this section becomes effective, makes his application within one year after the date this section becomes effective, such applicant may qualify by passing, satisfactorily, a written examination given by the Department of Health, in various branches of the chemistry of water.

Regulation 3. Chemical laboratory.—A holder of a permit shall maintain at all times a suitable chemical laboratory equipped to analyze water in accordance with the standard methods of water analyses as approved by the American Public Health Association, and the American Water Works Association for the following ingredients:—calcium, magnesium, acidity, silica, iron, zinc, copper, alkalinity to methyl orange, alkalinity to phenolphthalein, free carbon dioxide, and hydrogen ion concentration.

Regulation 4. Responsibility of Permittee.—The permittee shall at all times be held strictly responsible for the installation and maintenance of the mechanical device and for the addition of chemicals to the water supply in a building serviced by him. He may, however, delegate the actual addition of chemicals, the servicing of the mechanical device, and other related activities, to a qualified employee-operator, but such delegation shall not relieve the permittee from responsibility hereunder.

Regulation 5. Installations.—The mechanical device shall be so installed and located that it be at all times fully protected from tampering, exposure to any insanitary conditions, or the possibility of contamination. The storage of chemicals for use with the mechanical device shall be in metal containers kept locked at all times, and

such containers clearly marked to indicate that they hold chemicals for the treatment of the water supply.

Regulation 6. Report of installations and servicing.—Where a permittee has installed a mechanical device or where a permittee is servicing a mechanical device installed by one other than the permittee, the permittee shall within 24 hours after such installation, and in the latter case within 24 hours after the commencement of such servicing, file a report with the Sanitary Bureau of the Department of Health, on a 5- × 8-inch white or manila colored card, containing the following:

a. Address of premises.

b. Owner of premises.

c. Description of premises.

In the case of installation—

d. The undersigned has on....., 19.., installed at the aforesaid premises a mechanical device for the addition of chemicals to the water supply known as .....and will service said device with
Type
.....
Name of chemical or chemicals

Where the mechanical device to be serviced has been installed by one other than this permittee—

e. The undersigned has on....., 19.., commenced servicing the mechanical device heretofore installed at the aforesaid premises with.....
Name of chemical or chemicals

f. Permit number.....

.....
Name of Permittee
(If a corporation or partnership)

Dated:....., 19... By.....

Regulation 7. Samples of water.—The permittee at the time of the commencement of servicing, and at least once a month thereafter, shall take samples of the water before entering and after leaving the device and analyze such samples for increase in alkalinity, total hardness and silica content. These reports of analyses shall be kept on file, separately for each building, under street address, in the office of the permittee for a period of two years and shall be open for inspection by a representative of the Health Department.

Regulation 8. Discontinuance of use of mechanical device.—Where the servicing of a mechanical device for the addition of chemicals to

the water supply has been discontinued, it shall be the duty of the owner, lessee, or other person in charge of the building, to cause the device to be wholly disconnected from the water supply system and all openings therein properly sealed.

Regulation 9. Revocation of permit.—The Commissioner of Health may suspend or revoke a permit issued hereunder for cause; and may, after a hearing, revoke the approval of the mechanical device or apparatus theretofore found satisfactory, if he believes the health and safety of water consumers require such action.

Effective April 1, 1939.

(As adopted by the Board of Health December 12, 1938)

Note: Section 191 of the Sanitary Code is to be amended (in accordance with the instructions from the Board of Health, on December 12, 1938) to provide for an annual fee for a permit, for persons or firms to operate under newly adopted Section 170, above.

Automatic Control of Water Works

By C. Maxwell Stanley

AUTOMATIC control of water works plants should be of interest to operators and designers because of the opportunities it offers for improved service and economies, and because our dependency on such control will increase materially in the coming years. Whether or not we approve of automatic control, we should face the fact that it is well established in many other fields and that the trend is toward its greater use in water works. This paper endeavors to present a discussion of the subject, including some of the advantages and limitations of such control in its application to water works plants.

First of all, what do we mean by "automatic" control? The dictionary defines "automatic," when applied to machinery or mechanical devices, as "self-acting or self-regulating." No clearer explanation is needed for "self-acting or self-regulating" coincides exactly with the usual technical meaning associated with the term "automatic."

A simple self-acting, or automatic device, is the check valve which, upon the occurrence of a certain condition (cessation of flow in one direction), acts by itself to prevent flow in a reverse direction. A simple self-regulating, or automatic device, is the pressure reducing valve which operates by itself to maintain the pressure at a constant value. We may apply the term "automatic" to such simple devices as these and we may also apply the term to more complex and elaborate devices, or groups of devices, which may control by themselves, complete equipment for the pumping and treating of water. It is with this larger view that we are concerned.

It is my prediction that the application of automatic control of complete plants, or major portions thereof, will become commonplace

A paper presented at the Missouri Valley Section meeting, Des Moines, Iowa, October 14, 1938, by C. Maxwell Stanley, Cons. Eng., Young & Stanley, Inc., Muscatine, Iowa.

in water works systems because water works engineers will come to recognize the opportunities it affords for better and more economical service.

But today, many water works men are skeptical of anything labeled "automatic" and are slow to accept it. We hear objections to the thought of letting gadgets, relays, and switches control so necessary and important a service as the supply and treatment of water. We hear statements that automatic control will jeopardize the reliability and dependability of our water supply and endanger the health of our citizens. We hear complaints that faithful employees of long service will lose their jobs. These, and similar contentions, are the objections to automatic control of water plants.

Before we pass judgment, let us look at automatic control as found in other fields and then let us carefully consider its application to water works plants.

Application in Other Fields

In the industrial field, there is hardly a manufacturing plant that is not using automatic control to some extent. One of the classic examples is the huge machine developed a few years ago by the A. O. Smith Company for the manufacture of automobile frames. According to reports, it operates entirely automatically from the time raw material, in the form of steel plates and bars, is fed into one end of the machine until the completed frames come from the other. Within the machine, the steel is shaped, bent, fitted, welded and painted through automatic processes without manual control. The investment in this equipment controlled is far larger than the investment in the ordinary sized water works plant and the process is more complex.

In the field of sewage disposal, it is not unusual to find plants that operate automatically a greater part of each 24 hours without attendance. Of the numerous sewage disposal plants in the State of Iowa, there are only a very limited number that have operators on hand 24 hours of the day. The equipment used in these plants is similar to the equipment used in water treating plants.

In the field of power generation and distribution, we find universal application of automatic devices. It is not unusual to find hydroelectric generating plants, involving investments of hundreds of thousands of dollars, running without manual attendance. These plants start and stop automatically, synchronize themselves with

transmission lines, and protect the equipment within the plant. The only manual attention given them is periodical inspection, maintenance and janitor service. Automatic control has even been applied to diesel generating equipment, and plants have been constructed which start and stop automatically. Numerous substations and switching stations on electric transmission lines are designed to operate without manual control. Automatic equipment in the electric field is called upon to give dependable and continuous electric services, upon which people have come to rely almost as much as they do upon water. Indeed, a short interruption to electric service is apt to cause more inconvenience than a similar interruption in water service.

In still another field—that of transportation—we find general acceptance of automatic control. A number of railroads make use of automatic block systems to control the travel of trains and to prevent collision. In aviation, automatic equipment has been developed which permits a pilot to place a plane under its control in order to guide the plane and even to land it. Such applications as these in the transportation field are of vital interest to the safety of human life and have been adopted and used because they are considered more reliable than human beings.

These few examples indicate that automatic control is generally accepted and recognized in many fields on applications which involve large investment, which must give absolutely reliable and dependable service, and which must safeguard human life.

While it is true that we cannot directly apply to water plants many of the systems used in other fields, it is equally true that the vast experience in these fields has developed the basic principles of automatic control, as well as many of the individual devices which can be used in controlling water works plants.

Application to Pumping Plants

In analyzing the application of automatic control to water works, we shall consider pumping plants and treating plants separately.

Automatic control has been used in a number of pumping stations and the apparatus and its application to such equipment are fairly well developed. In a pumping plant, the primary concern is the starting and stopping of one or more pumps which are normally driven by electric motors. The starting and stopping of the pumps may be controlled by the water level in a reservoir or tank, by the

pressure in the mains, by the flow in the mains, by time, or by a remotely operated switch. Incidental to the primary problem of starting and stopping a pump, attention must be given to discharge and check valves, to the priming of the pump, to relief valves, to protective equipment for the motor, and other similar matters.

A number of articles have appeared in engineering periodicals in recent years describing the general application of automatic control to pumping equipment and describing particular installations. Two articles of general information one by S. A. Canariis (1) and one by H. A. Harris (2), present a very fine description of such application.

The experience of water works engineers with automatic control of pumping equipment has been generally satisfactory and has indicated that properly engineered and maintained equipment will come closer to perfect operation if automatically controlled than if manually operated. Automatic control has found an application in pumping plants because it has permitted economies of operation and has improved service.

Application to Treating Plants

As contrasted with the fairly wide use of automatic control in pumping plants, we find that such control has not been applied to treating plants in more than a few instances. The problems involved in a treating plant are naturally much different and more complex than those in a pumping plant. Automatic control in a pumping plant has but one primary operation—that of starting or stopping a pump. Such control in a treating plant must cover a number of different operations which may include feeding and regulation of chemicals; the operation of flocculators, agitators or similar mixing mechanism; the operation of mechanical apparatus in settling or clarification basins; the control of filters, including backwashing; the sterilization of water with chlorine; and the operation of booster and back-wash pumps.

The application of automatic control to a treating plant, including a majority of all of the steps listed above, requires very careful coordination of the various steps and is much more complex than that found in pumping plants. The problem, however, is not as difficult as would seem because most of the control devices required have already been developed and are available. The application of automatic control to such a plant is principally one of selection and arrangement of equipment and circuits. This fact can probably

best be shown by describing briefly two treating plants incorporating automatic features which our firm has recently designed.

The first of these treats a surface water collected in an impounding reservoir. The water flows from the reservoir through an aerator to an hydraulic jump channel where coagulants are introduced. From this channel the water flows through a series of baffled compartments and into a mixing basin where a rotating agitator is used. The water then flows by gravity through settling basins and thence on to the filters. From the filters, it goes to a clear well and is taken from the clear well by a booster pump and forced into the mains. Chlorine is added on the suction side of the pump.

The system of automatic control for this plant is as follows:

The booster pump is controlled either automatically from a float switch, located in the elevated tank on the system, or by a remote control switch located in the municipal electric plant about a mile from the water plant. This permits the operators in the electric plant to operate the pump to avoid periods of maximum demand on the electrical system. Before the booster pump can be started by either of these sources, it is necessary that water pressure and chlorine pressure be available at the chlorinator. If such pressures are not available, switches open the circuits so that the booster pump cannot be started. In such event, an indication is given in the power plant so the operator knows immediately that the pump has failed to start. If such pressures are proper, the chlorinator operates with the booster pump and feeds at a predetermined rate to suit the capacity of the pump.

A Float Switch Starts the Treating Process

After the booster pump has operated a sufficient period of time to reduce the level in the clear well below a predetermined point, a float switch closes a circuit which puts into motion the treating processes. The motors on the chemical feeder are started and these feed at a predetermined rate. The motor on the agitator is started and after both of these pieces of apparatus are in service, a solenoid on the rate of flow controllers on the filters is energized and the flow of water is started through the filters. As the flow of water starts through the filters, a constant level within the settling basin is maintained by means of a mechanically operated float control valve. The rate of flow controllers are set to maintain a constant rate of flow and the feeding of chemicals is adjusted to this flow.

In working out the automatic control for this particular plant, it was not necessary to develop any new devices, but merely to apply and coordinate equipment which was available. This plant has been operating automatically for over a year and the results have been entirely satisfactory. In fact, the operation has been far superior to what was formerly obtained with the unskilled operator who was employed. The plant described above does not have automatic back-washing equipment for the filters. The plant is visited at regular intervals, at which time an inspection of the equipment is made, janitor work is done, and routine maintenance is cared for. Back-washing of filters is done at the times of such visits.

Another example, of which there are several installations, is the automatic type of zeolite softening plant. A number of such plants have been installed in various parts of the country. One of these at Glidden, Iowa, has been described previously by the writer (3). This plant is fully automatic. It operates without attendance, except for daily inspection. The plant obtains its supply of water from two deep wells. Turbine-type pumps installed in these wells force the water through the zeolite plant and into the system. The starting and stopping of the pumps is controlled by a remotely located switch in the municipal electric plant. When the pumps are started, the water flows through zeolite softeners and into the mains. As it leaves the softeners, chemicals are added to reduce free carbon dioxide by means of a proportioner which operates automatically to supply the required amount relative to the flow of water.

The interesting feature of this plant is the provision made for regenerating and back-washing the zeolite filters. Each unit is provided with a master water meter arranged to make an electrical contact after a predetermined number of gallons of water have passed through the filter since the previous regeneration. The amount of water passing through the meter may be adjusted to suit the hardness of the water and the exchange capacity of the zeolite filters. When the electrical contact is made, it sets into operation a complete regenerating cycle controlled by an electrically operated multi-port rotary valve. The softener is first disconnected from the line and is back-washed with hard water directly from the well pumps for a period of 10 minutes. After the back-wash period is completed, a time switch changes the position of the rotary valve to the regeneration position and water is admitted to a hydraulic ejector which sucks salt brine from a brine measuring tank and injects it into the zeolite

filter. When the brine level in the brine measuring tank has fallen to a predetermined level, a float switch energizes the motor on the rotary valve which is moved to the rinse position.

The filter is then rinsed by water from the elevated tank for a period of approximately 50 minutes, after which, a time switch again energizes the motor on the rotary valve which is moved to the softening position. Two filters are installed at this plant with duplicate automatic controls. The automatic controls are interlocked so that it is impossible for both filters to be regenerated at the same time. If one filter should come up for regeneration during the regeneration period of the other filter, it is automatically held in the softening position until the regeneration period on the other filter has been completed.

Advantages of Automatic Control

The advantages of automatic control include the following:

1. More adequate protection of apparatus.
2. Greater reliability of service.
3. Improved quality of treatment.
4. Economy of operation.

Automatic control provides more adequate protection of apparatus and equipment because automatic devices act more quickly than human beings and are less apt to make mistakes. Properly designed and maintained automatic devices act instantaneously and there is not the chance of their becoming befuddled and doing the wrong thing, as may occur with the human operator. A completely automatic plant will provide protection which will prevent serious damage to the equipment.

Automatic control will provide greater reliability of service because it eliminates the opportunities of error of judgment which may be made by operators. The automatic plant will be put into service when it is required as a result of low pressure, low water level, or other similar occurrence, and will not be dependent upon the arrival or the judgment of an operator. Such plants will give service in the absence of coperators. Automatic control permits the giving of warnings, through alarms, of approaching conditions of low water level, etc., which will permit operators to take care of these items and avoid shut downs.

Automatic control will improve the quality of the treated water because it again eliminates the chance for human error and will

function continuously once it is properly adjusted. The feeding of chemicals, proportioned automatically to the flow of water through the plant, eliminates the opportunity of over or under dosage which may affect the quality of treated water. In an automatic plant, devices can be installed to keep the plant from operating until the chemicals feeding equipment is in proper condition.

Automatic operation will affect economy in operation with the saving of labor costs, or in saving of operating expenses. In many cases, an automatic plant can be operated with less personnel than with a manually operated plant. In all cases, savings in operation, resulting from decreased power consumption, reduced quantities of chemicals and elimination of expensive maintenance costs as the result of improved protection of equipment, will be found.

Objections to Automatic Control

There are some natural limitations to the application of automatic equipment. Such plants, to be successful, must be very capably designed and installed and the automatic equipment must be properly maintained. The maintenance of the electrical devices required to apply automatic control to a treating plant is not a complex job, but it is one that must be looked after at regular intervals and by competent employees. *Automatic control should not be considered if proper maintenance will not be available.*

There are other limitations that will result from the source of supply of water. For instance, some plants take their water from rivers with variations in turbidity and quality of the raw water so great from day to day and hour to hour that it would be difficult to adjust automatic control to follow the variations. Such a plant is not suited to such control.

The size of a plant will affect the desirability of application of automatic equipment. Large plants, which maintain a sizable personnel at all times, will not be as interested in automatic equipment as will smaller plants where definite savings can be made in labor costs.

In addition to the limitations mentioned above, there are, no doubt, many local conditions or peculiarities of plants which will limit or hinder the application of automatic equipment.

The three principal objections to the application of automatic control to water works plants seem to be:

1. The claim that automatic control will create unemployment.
2. The claim that automatic control is not sufficiently reliable for so essential a product as water.
3. The claim that automatic control will not provide adequate protection for expensive equipment.

It is my opinion that none of these objections can be substantiated in the face of a careful analysis.

Whether or not automatic control will cause unemployment depends entirely upon the local situation and the desires of the local governing body. It is very true that automatic control will release employees from long hours of tedious and routine services. However, the staffs of most water works plants are so overburdened with duties that automatic control, rather than reducing personnel, will permit the employees to look after their responsibilities adequately. In small communities, where new treating plants are considered, considered, automatic control may make it unnecessary to add personnel and may permit an improvement to be made that otherwise cannot be economically justified. In any case, there are sufficient advantages to automatic control to justify its application in many instances regardless of personnel. A decision as to whether there is to be a change in personnel is a local one and must be made in each plant. Automatic control of water works plants cannot be generally opposed on this basis.

The claim that automatic control is not sufficiently reliable for application to water plants is well answered by the extent to which such control is applied in other fields or processes much more complex than water systems, and in situations where human life is directly affected.

Likewise, any fear that automatic control will not provide suitable protection for the equipment within the plant is easily answered by observation of the practices in other fields of endeavor, where we find equipment of much greater value than that encountered in water works plants satisfactorily protected by automatic equipment.

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2. Harris, H. A., Jr. Experience with Automatic Control Equipment at Pumping Plants. Jour. A. W. W. A., **28:** 1170 (1936).
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Des Moines Iron Problem

By M. K. Tenny

IN ORDER intelligently to discuss the iron problem in the Des Moines water supply it is necessary to be familiar in a general way with the method of water collection used. The water supply for the city of Des Moines is taken from the Raccoon River valley. This is a glacial valley with an impervious blue clay bed covered by a layer of clean coarse sand averaging twenty or twenty-five feet deep, overlain with a surface soil of six feet or more. The Raccoon River meanders through this valley and tends to keep the sand layer saturated with water.

The shallow depth of the sand limits the possible draw-down and therefore tends to limit the methods that may be used for collecting water. In the method used, the water is collected by means of a gallery built of concrete rings, with open joints, and it is through these joints that the water is admitted (fig. 1). This gallery, as shown in fig. 2, is constructed in one continuous line, and runs parallel with the river and from 150 to 300 ft. from it, and is arranged to admit a draw-down of about six feet from low river water level. The gallery serves the double purpose of collecting water and of carrying it to the pumping station which is located at the downstream end.

Ordinarily this gallery has a capacity of somewhat less than one million gallons per day for each thousand linear feet. But this capacity may be increased by irrigating or flooding the ground on the opposite side of the gallery from the river with water pumped directly from the river into large shallow basins made by simply constructing a levee so as to prevent the water pumped onto the surface of the ground from flowing back into the river.

A paper presented at the Missouri Valley Section meeting held at Des Moines, Iowa, October 13, 1938, by M. K. Tenny, Asst. to Gen. Mgr., Des Moines Water Works, Des Moines.

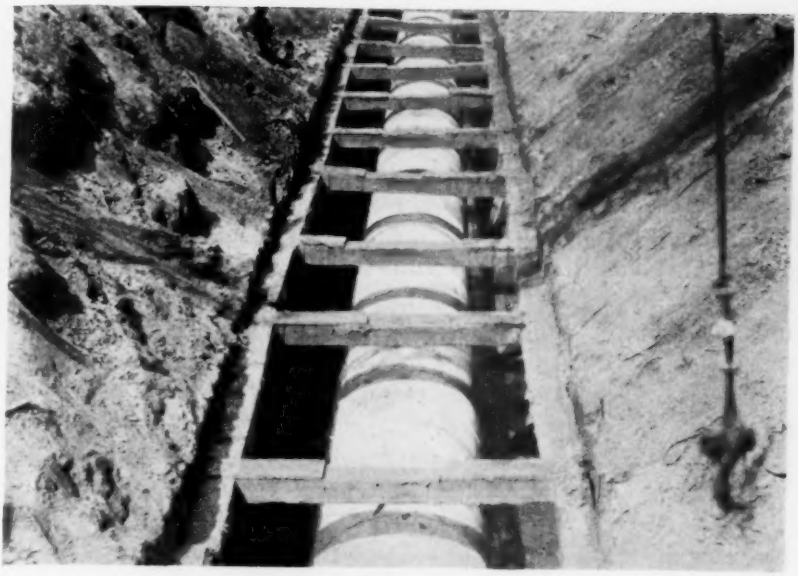

FIG. 1. GALLERY RINGS IN PLACE

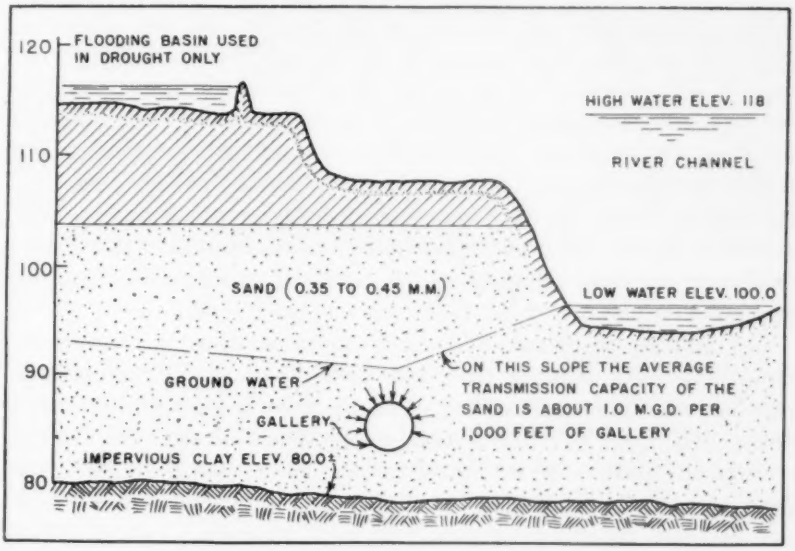

FIG. 2. TYPICAL SECTION OF FILTER GALLERY

Previous to 1924 the iron problem in the Des Moines city water supply had not seemed to require serious consideration. However, with the completion of a new section of gallery late in 1924, the iron content of the water rose rapidly, and in 1925 reached an amount which began to cause serious complaint. While in 1924 the iron content was only 0.110 p.p.m., by 1925 it had risen to an average of 0.450 p.p.m., remained about the same at 0.440 p.p.m. in 1926, and dropped to 0.197 p.p.m. in 1927. After 1927 it climbed successively during the next ten years, with the notable exception of 1932, when it dropped down to 0.323 p.p.m., and then continued on an upward trend, reaching an average of 0.648 p.p.m. in 1937. The sudden rise in 1925 is explained by the fact that, because the gallery system was completely open over its full length, a large portion of the water was coming from the new gallery at the upper end and the lower end was serving more or less as a conduit rather than as a collecting unit.

This new section of gallery was laid along the south side of the Raccoon River in an area where the river itself came fairly close to the bordering hill. The black soil of the higher ground, containing much organic matter, had been blown and washed down until it covered to a considerable depth the sand layer of the valley (fig. 3).

When rain water percolates through such a soil, the dissolved oxygen in the water is removed by the biological reducing action of the soil and carbon dioxide is liberated into the water. This resulting dilute carbonic acid solution of course dissolves the iron which occurs in the ground in almost unlimited quantities (probably as Fe_2O_3) and the iron then enters the gallery in solution as ferrous bicarbonate ($Fe\ H_2(CO_3)_2$). This process becomes much exaggerated when it is necessary to augment the natural rainfall by irrigating or flooding these areas adjacent to the gallery in order to build up the groundwater plane.

The amount of irrigation required depends upon a number of conditions. The bank of the river, used for natural filtration at a very low rate, gradually silts up. Its capacity is restored by a large flood. The flood of 1926, being the largest for a long time, cut the river bank extensively, and no irrigation was required in 1927. As time goes on, the bank again gradually silts up and increased irrigation becomes necessary until another flood makes a new cut. This cutting by a flood moves the material around and exposes a new surface. It may wash and regenerate or replace some of the clogged

sand, but much of the clogged material will remain somewhere in the valley after the flood.

Looking at the situation over a period of years, it is not surprising that the relative amount of irrigation is gradually increasing, and likewise the amount of iron in the supply increases with this additional irrigation.

There is another and more interesting feature to the iron problem in Des Moines and that is the growth of iron depositing bacteria in

FIG. 3. Strata of earth and black soil containing much organic matter deposited on top of the sand layer of the valley. Steel sheeting in foreground.

the gallery system. It appears that nature provides various means of preventing soluble salts in the ground from being too rapidly leached out and carried down the streams into the sea. One of the means of removing dissolved iron salts from ground waters seems to be found in the growth of certain bacteria which have the ability of precipitating the iron, from solution, as ferric hydroxide.

Opinions differ as to the mode whereby the bacteria withdraw iron from solution. Some investigators have maintained that the

deposition of iron hydroxide is one of the vital processes of the organism and as such is affected directly by the action of the living cell; others claim that the precipitation is purely chemical and is incidental rather than essential to bacteria life; and still others say that the accumulation is mechanical, particles of iron hydroxide present in the water being caught and held by mucilaginous parts of the bacteria. They may each be right, depending on varying conditions.

At any rate, the iron dissolved from the ground must enter the gallery, in solution, as ferrous bicarbonate in water free from oxygen

FIG. 4. IRON BACTERIA IN GALLERY WATER

and high in carbon dioxide. As this water mixes in the gallery with other water infiltering more directly from the river and containing comparatively high concentrations of dissolved oxygen, an optimum condition for the growth of iron bacteria results (fig. 4).

These organisms ordinarily start to grow at the inside surface of the gallery on the opposite side from the river, and extend their thread-like filamentous growth toward the center of the gallery, until, due to some unusually high rate of flow in the gallery, their fragile construction is broken, and voluminous portions of the growth

start to flow downstream. These portions become further broken up as the rate of flow becomes more rapid and as the water passes through the pump impellers, so that at the effluent from the pumps their effect is to produce a reddish colored water.

Previous to 1930 this used to be the cause of occasions of red water usually occurring on Monday morning, due to the increased consumption by housewives doing the family washing. Naturally this condition was not well received by those doing the laundry. The city water board did not feel financially able to construct an iron removal plant and it therefore became necessary to seek cheaper if less efficient methods of ameliorating the bad situation. Consequently, early in 1930 a high dosage of chlorine was introduced at the upper end of the gallery.

The concentration of chlorine in this upper portion of the gallery was kept high enough to inhibit growth of iron bacteria in any considerable volume and as the chlorine concentration became diluted in the lower part of the gallery the rate of flow became rapid enough to prevent accumulation of growth. In this way the red water problem was taken care of, but of course none of the iron was actually removed from the water. Also growth of the organisms in the passages outside of the channel in the gallery—to which the chlorine does not penetrate—was not inhibited, so that a large part of the iron in the gallery water is still in the form of ferric hydroxide on carcasses of these iron bacteria, but they are not now allowed to accumulate in large enough volume to let go in slugs, and thus cause so-called red water.

The iron bacteria found growing in the galleries in Des Moines are *Spirophyllum*, *Gallionella*, *Cladothrix* and *Leptothrix* (figs. 5–8). Typical *Crenothrix* has not been found. This is not surprising, as *Crenothrix* occurs more rarely than the other iron thread bacteria and is usually found only in well water after it has passed through city distributing pipes. It is perhaps unfortunate that it has become common with some water works engineers to lump all of the iron thread bacteria together and call them *Crenothrix*, because a differentiation between the various types is of some importance in the consideration of a local problem such as that in Des Moines.

Spirophyllum and *Gallionella* are the most prevalent in the Des Moines water supply. It is believed that these two types of organisms precipitate ferric hydroxide from solutions of ferrous bicarbonate and use the carbon dioxide liberated and the energy pro-

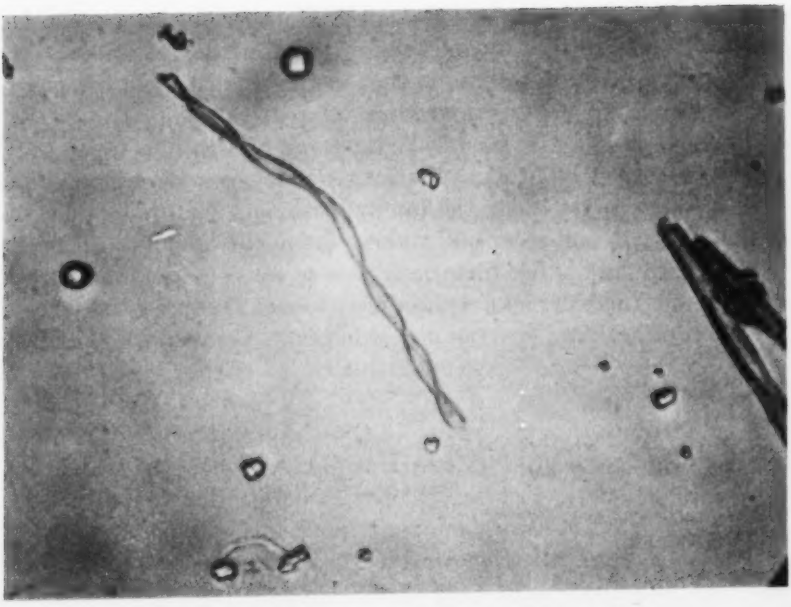

FIG. 5. *Spirophyllum* (magnified 1,400 times)

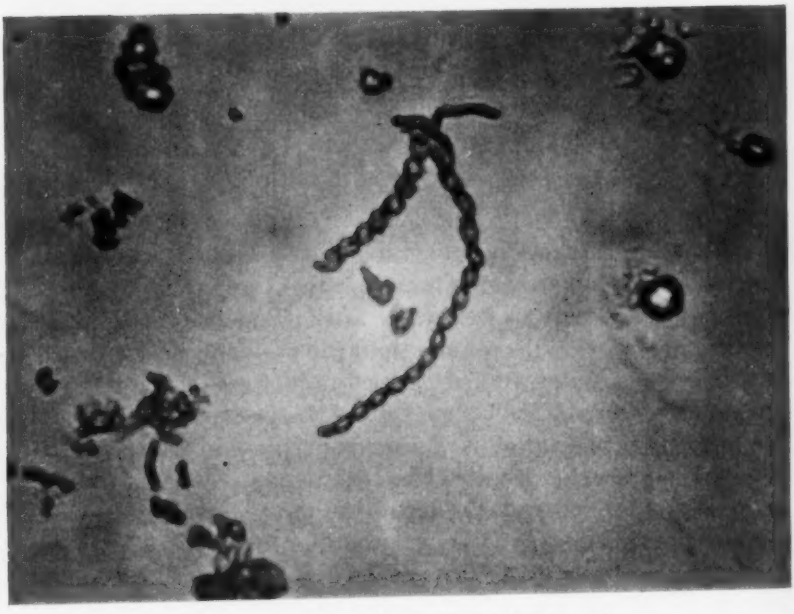

FIG. 6. *Gallionella* (magnified 1,400 times)

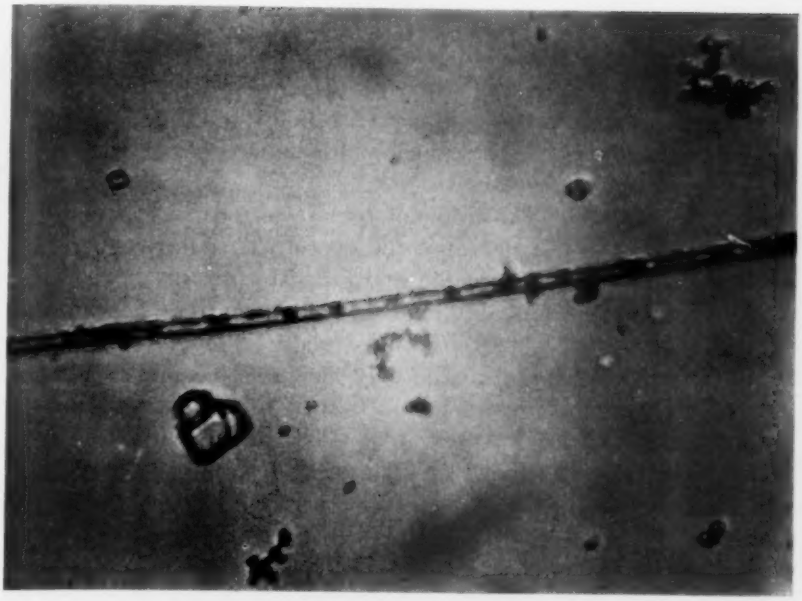

FIG. 7. *Cladothrix* (magnified 1,400 times)

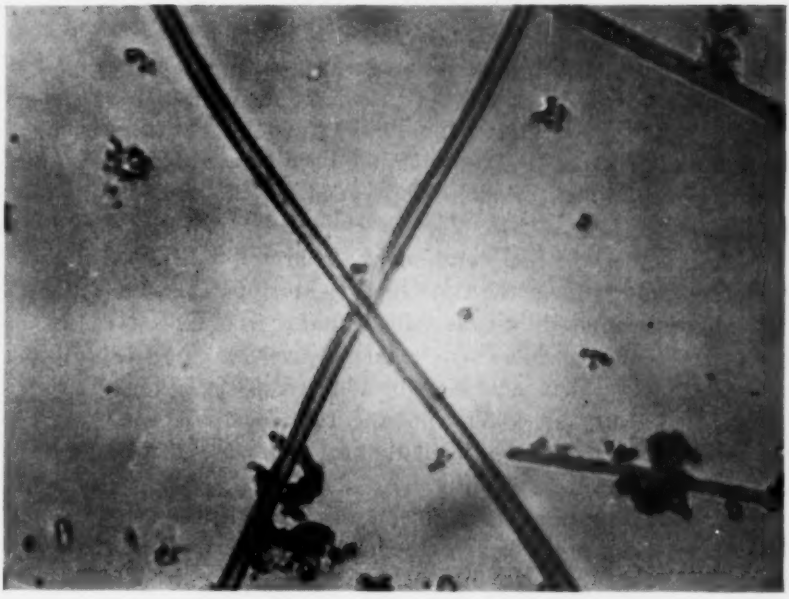

FIG. 8. *Leptothrix* (magnified 1,400 times)

duced during oxidation for their life processes. It is therefore essential that ferrous bicarbonate be present for their growth. It has been found that atmospheric oxygen is also absolutely necessary but if oxygen is present in too high concentration it will inhibit growth. For optimum growth the oxygen content is between 0.1 and 0.3 parts per million.

Leptothrix and *Cladothrix* do not require ferrous bicarbonate for their life processes but do cause the deposition of ferric hydroxide when either inorganic or organic iron salts are present. *Leptothrix*, unlike *Spirophyllum*, probably requires organic matter as a source of carbon for its growth but like *Spirophyllum* it is aerobic. *Cladothrix* is a widespread soil organism and may grow in the complete absence of iron but if iron is present it will deposit ferric hydroxide on its sheath.

Quite probably the purpose in nature, of the iron bacteria, as mentioned before, is to take dissolved iron out of solution in the ground, and in such a rôle they have no doubt played an important part in the formation of ocherous deposits of bog iron ore. It is not impossible that they may act in a similar rôle to the advantage of water works engineers. Laboratory tests made in Des Moines show that the gallery water with a total iron content of from 0.6 to 1.0 p.p.m., filtered through a sand and gravel layer two and a half feet thick, gave an effluent containing less than 0.1 p.p.m. iron. This was without aeration or any other treatment of the water. This effluent water was found to be considerably less corrosive than a similar gallery water sample which had been aerated before filtration and which contained considerable oxygen as well as dissolved carbon dioxide.

Probably the eventual solution of the iron problem in the Des Moines supply will be the construction and operation of a softening plant as soon as the city is able to finance such a project. In the meantime some consideration is being given to the idea of constructing filters which could later be adapted to the softening process but be used at present to filter out the iron which is in the water, for the most part, on the sheaths of the dead carcasses of iron bacteria and as such quite readily filterable.

The cost of amortization of such a plant, particularly if it be built with P. W. A. or W. P. A. help, together with the small cost of operation, would be only about one-third the total annual cost of building and operating a softening plant.

Promoting the Use of Water

By Max K. Socha

ALL are familiar with the current and overworked slang phrase "I think you've got something there!" The Los Angeles Bureau of Water Works and Supply believes that it has something in its program to promote the use of water. In the several years that I have been a member of this Association, the subject has received far too little discussion. I believe that it is a subject which will be of increasing importance in the future. After a discussion of the problem in general, I shall describe our helpful and beneficial plan for the promotion of the use of water in order to increase revenue.

The early settlers of California found a region blessed with an ideal climate, fertile valleys, and abundant natural resources. The only element lacking to create an agricultural and industrial empire was an adequate supply of water. Faced with an annual dry period of six months, water became the life blood of the state. Wherever water was applied, the desert was converted into rich and fertile agricultural communities and thriving cities. As the communities developed, the water works organizations were faced with a constant problem of securing an adequate supply of water. Underground and other local sources of supply became depleted and inadequate. It became necessary to preach and practice conservation, even to the extent of restricting the use of water.

We still preach water conservation, but it has taken a different form, and today it is manifested in the development of projects which have been, or are being, built, projects such as the Owens River, Hetch-Hetchy, and Mokelumne Aqueducts serving our great cities; and also the Central Valley, Mono Basin, All-American Canal and Colorado River Aqueduct projects. Each of these, although

A paper presented at the California Section meeting, Riverside, California, October 27, 1938, by Max K. Socha, Asst. Civil Eng., Dept. of Water and Power, Los Angeles.

being constructed by separate entities, is a part of a correlative whole in the ultimate development of the state water resources. Far-sighted engineers have designed these water systems to meet the demands for years to come, and thus many communities are faced with an overabundance of water supply at the present time.

Many economic experts have come to the conclusion that the population of the United States is rapidly approaching a level of stability and will reach that point within twenty years, with an ultimate population of approximately 150 million. This is due to our changing economic conditions, restriction of immigration, and the attainment of a stage of full development in the country as a whole. Due to its natural advantages, California in all probability will continue to develop at a faster rate than the rest of the nation, but nevertheless it can be assumed that the rate of growth of the state will not continue as rapidly as in the past. Therefore, with the full development of the state's water resources, we can expect to obtain a permanent adequate supply of water.

In addition to securing a sufficient water supply, it has been necessary to improve constantly the quality and service of the water system. Practices unknown a few years ago such as chlorination, filtration, and bacteriological control, have now become standard practices of all progressive water systems. Distribution mains have been constantly increased in size to provide higher pressures and better fire protection, with the resultant lowering of fire in-insurance rates. Water mains now receive a protective coating against corrosion; dead ends have been eliminated; double end supplies are made available; and fire hydrants are placed at more frequent intervals; all to assure an abundant supply of water to meet emergencies as well as normal demands upon the system.

The development of water supply and improvement of local water systems have progressed at such a rapid rate that it has been necessary to finance these improvements through the issuance of bonds rather than through revenue. The redemption of these bonds is scheduled by the anticipation of future revenue, and if the necessary bond interest and redemption funds are not to become a financial burden on the water works organization, it is apparent that the revenues from the water sales must be increased to maintain the water works system on a solvent basis.

A great portion of the capital improvements toward increasing the water supply and improving the service and distribution remains as a

fixed charge which is not affected by the quantity of water consumed and consequently any increase in consumption will create a surplus in operating revenue to meet future demands. Water works systems, to a large extent, are municipal enterprises and the element of profit from water sales is of secondary consideration. However, in order to meet the constantly necessary improvements and emergencies which may arise, it is necessary to maintain an adequate surplus of working capital. This can be done only through the increase of revenues placing the organization on a sound financial basis.

One of the most feasible methods of increasing revenues is the furtherance of the use of water. Before a campaign for increasing consumption is organized, the supply and distribution systems must, of course, be able to meet the increased demands. A rate structure also must be developed in which water may be supplied at rates which are greater than the cost of delivering the water so that the campaign will result in accumulating surplus funds over and above the fixed charges of operation and maintenance.

Work of Other Utilities

In organizing a campaign for the increased use of water, it is well to consider what has been done along this line by other utilities. The electric and gas utilities have, for some time, carried on intensive appliance sales promotion campaigns and extensive advertisements of the merits of the respective appliances. Since such campaigns have been carried on continuously for a considerable length of time, it may be assumed that the resultant increase in revenues has been financially profitable to these utilities and has also more than offset the expense of carrying on such campaigns. The salient features of these campaigns have been the establishment of easy-payment plans and the interesting of architects, builders, artisans, and home owners in the merits of incorporating electrical or gas consuming features in their homes. Technical advice is freely given and prospective purchasers are invited to consult with experts on the design, location and advisability of the types of these appliances. An attempt has been made to make the general public electric-conscious, or gas-conscious, (as the case may be), and stress has been given to labor-saving devices and the desire for more leisure.

The various uses of water are naturally more limited than those of electricity, but there are several means by which consumption can be increased through an adequate promotion of these uses. The ad-

vantages of lawn sprinkling systems are immediately apparent. Lawns equipped with sprinkling systems can be maintained in the finest condition with a minimum of effort. Sprinkling systems save long hours of laborious hose watering and, due to the ease of operation, lawns naturally receive more care and more frequent watering by the use of sprinkling systems, all of which results in a greater consumption of water. The initial cost of installing sprinkling systems has long retarded their universal use, but with modern means of financing, such as the Modernization Loans of the Federal Housing Administration, the system can be installed on a low monthly payment plan. Plumbing associations can be encouraged to coöperate in promoting the installation of lawn sprinkling systems and to handle all necessary details of obtaining F.H.A. loans for financing the installation.

Swimming Pools for Greater Consumption

Through the F.H.A., and other means, it is now possible for the home owners to carry on extensive modernization alterations in their homes. Thousands of homes are not equipped with showers. If showers are installed in these homes, the refreshing morning dip will become a ritual in countless homes, with the water meters registering when they would otherwise be idle. In furthering the installation of showers, the fullest coöperation would immediately be obtained from the plumbing establishments, material supply houses, builders, and architects, who would be mutually benefited by these improvements.

Large sections of our California cities are blessed with rather extensive grounds around individual homes. Many of these are large enough so that small swimming pools could be installed. The expense of swimming pool installation has, in the past, discouraged any extensive construction. Studies could be made of economical and inexpensive designs for small swimming pools and standardized plans could be developed by water department engineering forces. Accurate cost estimates could be made of various types to fit the purse of each individual. Contacts could be made with contractors specializing in this type of construction; and the installation of pools generally encouraged.

Our ideal California climate is conducive to the establishment of water effects in private gardens. Fountains, bird baths, fish pools, and water lily gardens should be encouraged. Likewise, plans for

this type of construction could be developed and advisory service performed by the water department.

Several months ago, the Los Angeles Bureau of Water Works and Supply decided to initiate a program for the furtherance of the use of water. A committee was organized, composed of various engineers of the Bureau, to discuss and devise plans for carrying on such a campaign. Our first efforts were directed along the lines of encouraging home gardens and disseminating information and advice relative to the proper preparation of soil and the culture of plants. It was felt that this effort would immediately appeal to the general public, fill a need of home owners for advice in the development of their gardens, and stimulate an additional water use through arousing consumers' interest in gardening activites. The campaign would also result in a vast program of civic beautification.

We explained our program to representatives of the Southern California Horticultural Institute in an endeavor to enlist their cooperation. An immediate enthusiastic response was obtained as the Institute foresaw the tremendous possibilities of mutual benefits to both themselves and the water bureau. In July of this year, we brought into being a monthly leaflet or pamphlet entitled "Your Garden" and published in coöperation with the Horticultural Institute. The publication contains authentic, timely and practical information on gardening and is mailed out with the monthly water bills.

Management of the Publication

The data and material for "Your Garden" are supplied by members of the Horticultural Institute. This material is submitted to the water bureau which selects the proper subjects to be included each month and then transmits the material to the editor. We selected an editor with wide experience in the publishing of garden magazines, and with technical ability and training along the lines of writing for appeal to the general public. It was felt that the material would best be edited by one with experience along this line rather than by inexperienced individuals in the water bureau. The bureau's selection of the material to be included each month prevents the inclusion of undesirable articles or personal advertisement by the originator of the material. It also enables us to control and expand the subject matter to include other things in our program of the furtherance of the use of water.

The Department of Water and Power mails out monthly approximately 465,000 water and power bills. We thus are reaching an enormous number of people by utilizing this method of distribution, with no increase in cost over the normal billing costs of the department. About 10,000 additional bulletins are secured for distribution through the Water Sales Division and the Branch Commercial Offices of the department. Thus, approximately 475,000 "Your Garden" bulletins are reaching consumers each month.

The annual cost for publication of "Your Garden" is approximately $21,000. There are nearly 280,000 active water meters in service within the city of Los Angeles. The Los Angeles water rate structure is based on a unit of 100 cubic feet, and it is estimated that if our program could increase the consumption of each consumer so that his meter reading would fall in the next 100-cubic-foot bracket, the increase in revenue would amount to approximately $50,000 a month, or $600,000 annually.

Success of the Program

The publication of "Your Garden" has been carried on now for four months and we have received an immediate and enthusiastic response from the general public. Complimentary copies of the first issue were mailed to every woman's club, to garden clubs, and organizations of a similar nature, together with a letter explaining our aims and purposes in carrying on the publication. It is still too early to determine the effect of our stimulation to home gardening by this means. The material used in "Your Garden" is not designed to effect immediately a widespread increase in water consumption but is expected to arouse a permanent interest in home gardening as a hobby or recreational avocation, and as a means of civic beautification. By the furnishing of useful information in simple language to the amateur gardener, we expect to obtain a slow but permanent increase in per capita consumption of water within the city.

To stimulate continuing interest in "Your Garden," the bureau has made available a fabrikoid loose leaf binder, designed to facilitate the filing of the monthly issues into a permanent record. All issues up to the present have contained an announcement that by means of clipping the coupon, the cover could be obtained by sending in ten cents to the office of the bureau. The success of the program is evidenced by the fact that over 11,000 consumers sent in their dimes to secure the binder during the first three months. Requests are

being received at the rate of over 125 per day, indicating a continuing interest. The success and enthusiastic reception of the general public of "Your Garden" has made it a permanent publication of the bureau and the subject matter will be expanded to include pertinent data and advice on such other elements as fish ponds, swimming pools, fountains, and lawn sprinkling systems.

A few words of caution will help those who are contemplating a similar program. Avoid such pitfalls as garden competitions. If you must have things of this nature, let the Parent-Teachers' Associations and other organizations sponsor the competition. Obtain public confidence in your campaign by avoiding direct advertisement of your product. Cultivate interest in gardening by timely and beneficial advice. The increase in water consumption will be a natural and permanent result of this stimulus. Do not attempt to establish a question and answer bureau, but refer all such inquiries to technical experts such as nurserymen. Control the material for your campaign. Do not let outside interests direct the course of the program for their own individual interests. Avoid controversial issues. Conduct your campaign to promote goodwill with the consumer and with a view to performing a public service.

Service to Irrigation Consumers

In addition to the furtherance of the use of water by domestic consumers, the Los Angeles Bureau of Water Works and Supply has initiated a program of coöperation and service to its irrigation consumers in the San Fernando Valley. There are over 4,000 irrigation service meters in this area of the city, which, by means of an adequate water supply from the Owens River Aqueduct, has been transformed from a grazing and dry farming area of little value to a rich and fertile agricultural community. The climate, soil, and location within the immediate confines of a large city, with a large consuming outlet for its products, have made possible the production of many varied and profitable crops within the valley.

It is of vital interest to the water bureau that its irrigation consumers in the valley be on a firm financial basis and therefore the bureau is now coöperating with the Bureau of Agricultural Engineering of the United States Department of Agriculture and the College of Agriculture of the University of California, in connection with a survey and final report involving an agricultural and economic survey of agricultural conditions in the San Fernando Valley. This in-

vestigation and report will go into all matters involving the success of the city farmer located in the San Fernando Valley. It will include data on taxation, overlapping assessments, cost of production, including water, and all other factors which go to make up the success or failure of the farmer in the valley.

The water bureau is now working out final details, in coöperation with the Bureau of Agricultural Engineering of the United States Department of Agriculture, regarding investigation and reports involving data on the application or other use of water in the San Fernando Valley. The field investigation for this work will probably cover a period of not less than five years. Certain small areas located in the Valley will be set aside for experimental purposes in connection with the irrigation and production of all types of agricultural crops common to the region. These crops will include such ones as citrus, beans, sugar beets, etc. Various methods of irrigation will be investigated, including irrigation by low-head sprinkling systems, narrow and wide furrows, and flooding. Accurate cost data will be assembled; duty of water data will be collected; soil moisture tests and chemical analysis of water will be made; boron in the Owens Valley water and its effect on San Fernando Valley crops will be studied; efforts will be made to introduce new crops; and there will be a study of the possibility of growing certain tropical flowering trees for shade and beautification purposes throughout the city.

At the present time, the water bureau is working in coöperation with the Office of Experimental Stations of the United States Department of Agriculture, the Los Angeles County Farm Bureau, and other organizations on the study of the natural economic resources of California, and especially Southern California, in connection with the location of a research laboratory to be established at some logical location in the eleven western states, including the Territory of Hawaii. A recent Amended Act of Congress under the Agricultural Adjustment Act, set aside an annual sum of four million dollars for the establishment of four regional research laboratories in the United States. The object of the laboratory will be to study, from the viewpoint of possible by-products, all agricultural crops raised in America. The western regional laboratory, which may be located at, or near, Los Angeles, will involve a study of all citrus crops, alfalfa, potatoes and wheat. The four laboratories must be located near university centers where the staff to be employed by the Government will be enabled to carry on better its research studies and

have nearby technical libraries and other technical personnel to assist in the research investigation.

The Los Angeles Water Bureau at the present time is contemplating a general beautification program for the city, in coöperation with various organizations within the city, such as the Beautification Committee of the Los Angeles Chamber of Commerce, the Parent-Teachers' Association, and other similar organizations. The program will take considerable time to be placed in final effect, as many details must be worked out and efforts of this kind depend, not on individual efforts, but on the coöperative enterprise of community districts and interested organizations. We are coöperating in investigation of the planting and growing of certain trees and flowers at a site below the Stone Canyon Dam, and at a new site to be located on the west side of the Upper San Fernando Reservoir.

The furtherance of a greater use of water by these methods and others which may be developed, will not only assure the placing of water systems on a sound financial basis but will encourage the enjoyment by the community at large of the many advantageous but undeveloped uses and effects of water, and promote a higher standard of living and a fuller enjoyment of life by each individual.

Gadgets Become Standard Equipment

By George C. Sopp

OBSOLESCENCE of machinery and equipment has always been a vital element to be considered in production fields. This element must of necessity be carefully studied and provided for in the price of any commodity or service which is offered for sale. Equipment becomes obsolete due either to normal wear, being poorly adapted for the job, or because of the inability of the particular piece of equipment or machinery to keep pace with the ever increasing production schedules. In many cases, however, obsolescence may be avoided or at least postponed merely by making simple improvements or adjustments in existing equipment which will enable it to produce a maximum of output or use.

In water works throughout the country, the cost of supplying water to the consumers and the efficiency of men and machinery are in direct ratio to each other. This predominant factor, called efficiency, is an important item in the cost of supplying water, especially where the utility is a publicly owned institution such as the Bureau of Water Works and Supply of the Department of Water and Power of the city of Los Angeles.

The several examples herein described and illustrated show some of the improvements in equipment that have been developed principally for use in the Meter and Service Division. This equipment was built in the department shops, or manufactured outside under our specifications and direct supervision.

It is hoped that our efforts along this line may afford some helpful ideas to others in the study of similar problems.

Improvements in machines for tapping and inserting 1½-inch and 2-inch corporation cocks into cast-iron water mains in Los Angeles have materially increased the efficiency of such equipment.

A paper presented at the California Section meeting, Riverside, California, October 27, 1938, by George C. Sopp, Meter and Service Inspector, Bureau of Water Works and Supply, Los Angeles.

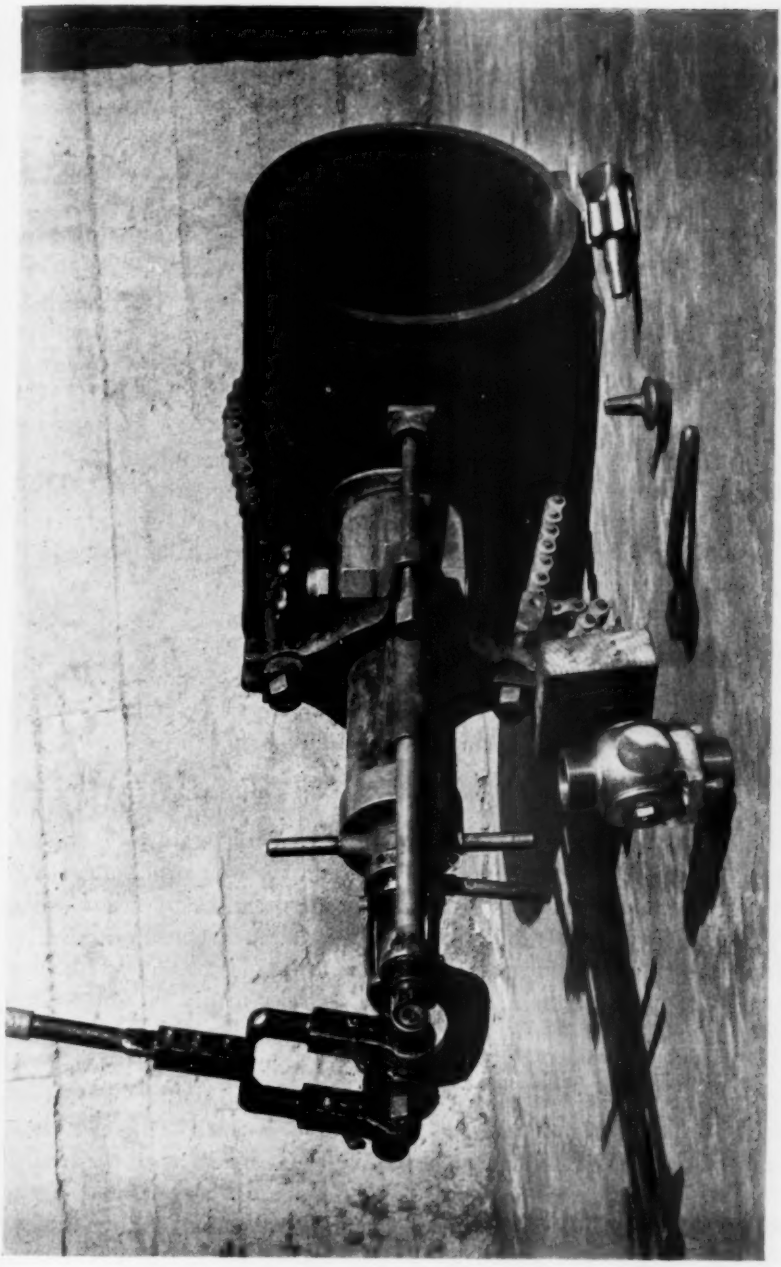

FIG. 1. IMPROVED TAPPING MACHINE, FOR INSERTING 1¼- AND 2-INCH CORPORATION COCKS INTO CAST-IRON WATER MAINS

Corporation cocks of the 1½-inch size are not inserted into cast-iron mains smaller than 10-inch, and 2-inch corporation cocks are not inserted into cast-iron mains smaller than 12-inch, depending on the wall thickness of the pipe. Corporation cocks in these sizes are inserted a little above the center of the main, so as to avoid anything that may be floating along the top or rolling along the bottom of the main being drawn into the service connection pipe or meter. Also, this allows a slight arching of the service pipe from the tap hole to the foot of the riser at the meter, which is a desirable feature in respect to settling of the service connection pipe.

A boring bar equipped with a combined drill and tap is used to drill a hole through the wall of the main and to thread the hole to correspond with the threads on the corporation cock (see fig. 1).

As tapping of the main is made horizontally, and the weight of our special 1½-inch and 2-inch corporation cocks is considerably more than the combined weight of the drill and tap, sagging of the boring bar would occur when the drill and tap are removed and the corporation cock affixed, and hence the threads on the corporation cock when it is being inserted into the main would not properly engage with the threads in the hole through the wall of the main. Proper engagement of these threads is, of course, absolutely essential, and to accomplish this the boring bar is equipped at the drill end with a cross head which is notched to fit guides welded along the inside of the barrel of the machine. In this way, sagging of the boring bar is eliminated, and the threads of the corporation cock are made to engage properly the threaded hole through the wall of the main.

As most tapping machines are fastened to the main by a single chain, and since the machine's tapping saddle rests on a rubber gasket, rocking of the machine parallel with the main can easily occur when drilling the hole or threading same. This trouble has been practically eliminated by equipping the barrel of the tapping machine with two stout steel braces which are adjusted to seat firmly on the main. This improvement lessens the danger of binding and breaking the drill tap, insures better threading of the hole through the wall of the main, and also insures easier operation of the boring bar. The chain anchors the machine against an up-and-down tendency, and the braces prevent the machine from rocking parallel with the main.

As the boring bar for most tapping machines is operated by a ratchet with the handle at right angles to the boring bar, the thrust is at right angles to the boring bar and machine. This thrust tends

to bind the drill and put considerable strain on the devices for clamping the tapping machine to the main. To overcome this trouble an automobile differential is attached to the barrel of the tapping machine. This gearing with a double ratchet makes it possible to revolve the boring bar by pushing and pulling directly toward or away from the water main, thereby practically eliminating side thrust on the boring bar or machine.

It does a better job, makes the work easier, and lessens pavement cutting and trench digging. This is a good example of improvements

FIG. 2. IMPROVED 1½- AND 2-INCH CORPORATION COCKS

made on standard equipment to produce a more efficient piece of machinery.

Where 1½- and 2-inch corporation cocks are inserted into cast-iron water mains in the Los Angeles water system, the connections are made more secure by having the corporation cock equipped with a special flange on the inlet side (see fig. 2). This flange is about ⅜ inch thick, is cast integrally with the fitting, and has a triangular periphery. It is drilled and threaded for three ½-inch bronze set screws; two of these screws are placed at the bottom of the flange where bracing is most needed. After the corporation cock is properly

screwed into the wall of the main, these set screws are backed out of the flange until they make a tight contact with the main. These screws brace the corporation cock so that it cannot be easily broken off at the main but must be pulled practically straight out of the tapped hole into which it is screwed.

We have tested the efficiency of these braces by connecting a piece of 2-inch pipe to the corporation cock and loading such pipe so as to exert a greater strain on the corporation cock than would occur in actual service, and the braces held the corporation cock firmly. While the loading was on the 2-inch pipe, the bracing of the set screws was slowly released; the corporation cock began to sag immediately, stripped the threading and broke out of the main.

To lessen further the strain on the threads of the corporation cock when inserted in the main, a bronze fitting having a bell end is screwed on to the corporation cock. The service connection pipe is leaded into this bell end, making a semiflexible joint which is desirable in case there should be any heavy settling of the service pipe.

This improvement in the corporation cock, and the semi-flexible joint for the service pipe, have added much to its rigidity when in place, thereby increasing its life and usefulness in service.

Water Meter Connection and Pipe Insulator

A few complaints have been received by the water bureau from consumers claiming that the water from their taps appeared cloudy. This cloudy condition is believed to be caused principally by the action of the zinc in the galvanized coating of the consumer's pipe coming in contact with carbonates and dissolved oxygen in the water, forming zinc salts. The rate at which these salts are formed is greatly increased by the passage of an electric current through the water due to cell action between two dissimilar metals that are in physical contact with each other. Such cell action of considerable capacity is formed by the copper service connection tubing, used by the water bureau between the main and the meter, and the galvanized iron or steel pipe used by the consumer.

If the two pipe systems are separated physically from each other by means of an insulating sleeve, and provided the potentials existing between them internally due to the water and externally due to the soil are practically equal, there will be very little if any current flow between metals through the water, and the formation of zinc salts will be reduced to a minimum.

The department has developed a meter connection (fig. 3) containing an insulated sleeve or tail piece for this purpose, and it is placed at the outlet side of the meter. This connection is made in two sections, one section screws on to the spud of the meter and the other slips over the consumer's pipe from which it is thoroughly insulated by a piece of hard vulcanized rubber tube 1 in. long and $\frac{3}{16}$ in. thick. Connection to the consumer's pipe is made watertight by slipping a semi-hard rubber ring over the consumer's pipe and then screwing the two sections together, this semi-hard ring being squeezed tightly around and against the consumer's pipe to make a watertight joint.

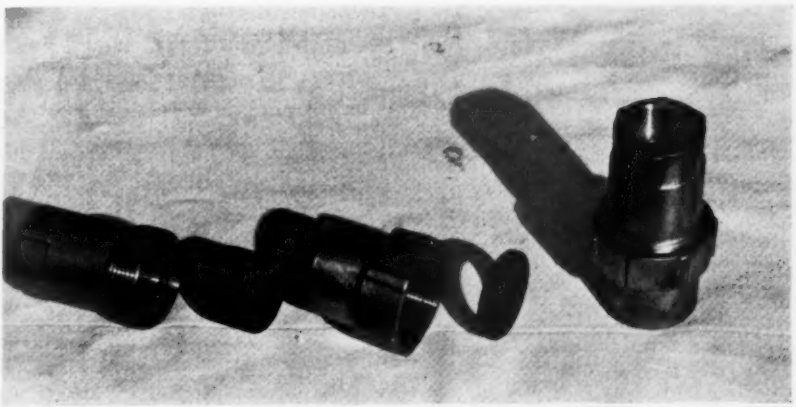

FIG. 3. WATER METER CONNECTION AND PIPE INSULATOR

As it will be necessary, when removing or changing a meter where such fitting has been installed, to slide the insulated section and the semi-hard ring along the consumer's pipe, the surface of such pipe should be smooth, round and well galvanized and remain so. In order to accomplish this the department intends to pick out galvanized iron pipe having such requirements and cut it up into pieces about six inches in length. These pieces will be threaded on one end and be equipped with a galvanized iron coupling without abrasing the galvanizing on the nipple. The pipe wrench will be placed on the coupling to eliminate marring of the galvanizing on the nipple when connecting same to the consumer's pipe.

If found necessary, we intend to have this nipple and socket regalvanized, or we may use smooth black pipe and have it well galvanized.

Cloudy water also may occur through copper having been dissolved by the water flowing through the copper tubing, and which upon reaching the galvanized piping causes zinc to go into solution. This insulated meter connection will not prevent this happening, nor will it prevent zinc dissolving from the galvanized iron pipe by the water flowing through it. However, if the cloudiness is mostly due to copper tubing coming in physical contact through the meter with the consumer's pipe, such trouble will be materially reduced. This cloudy water condition occurs immediately after copper tube service connection is installed, and appears to clear up in about two or three weeks.

Copper tubing is used in a great many cities for water service connection work because it has a far longer life than galvanized iron or steel, or cast-iron pipe under some soil condition. It does not form rust to reduce its carrying capacity, it is flexible with the corporation cock at the main, and its maintenance cost is far less, especially when laid in streets that are heavily paved.

Meter Register Lubricating Grease Gun

Due to meter register trouble caused by corrosion, this department conceived the idea of using rubber bushings for the spindle bearings in both the top and the bottom plates of the register. This practice has eliminated nearly all the corrosion as far as the spindle bearings are concerned, but it has not eliminated corrosion of the pinion and spur gears, which is accelerated by the gears constantly changing back and forth between a wet and dry condition.

As necessity is the mother of invention, we finally decided to grease these spur and pinion gears. Our meter registers being equipped with what we call a dust ring, we decided to use this dust ring for a grease retainer.

The next thing was to obtain a grease that would not become so hard in cold weather as to cause a drag on the gearing, nor so soft in warm weather as to cause running or slumping out, and that would be lasting and not emulsify in water and thus lose its lubricating qualities.

After considerable experimenting we eventually found a grease which we think is giving splendid service. Its specifications are as follows:

> Pale or neutral mineral oil; pour test not to exceed 15°F.; viscosity 400 seconds minimum at 100°F. (Saybolt Universal Test); aluminum soap, 10.5 to 11.5 per cent; melting point,

185° to 195°F.; grease shall not emulsify in water; and grease shall contain no free caustic or lime.

The next question was how to place the grease in the register. After considerable thought we decided to make a grease gun similar to that used for automobiles (fig. 4). It consists, essentially, of a short piece of 4-inch pipe mounted on short legs which are fastened on a board so that it will be portable and convenient for use on a shop work bench. The cylinder is mounted horizontally and is fitted on one end with a threaded cap through which a piston is operated by a hand crank. The piston puts pressure on the grease within the cylinder and the operator holds the meter register on a

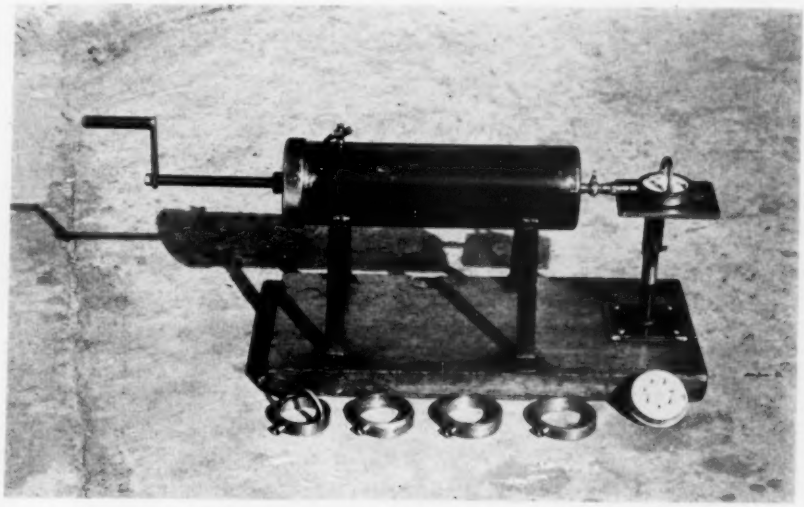

FIG. 4. METER REGISTER LUBRICATING GREASE GUN

frame at the opposite end of the cylinder against a pet cock. As it is necessary only occasionally to renew the pressure in the cylinder, the operator can use one hand for holding the register and the other for releasing the grease through the pet cock into the register as desired.

Experience is necessary to enable the operator to judge how much grease to use for each register. The quantity should be sufficient only to surround completely the entire gearing between the top and bottom plates and the register casing ring. If much more is used it is apt to be forced through the spindle bearings in the register top plate and appear on the face of the register.

Due to the size of the cylinder it was found necessary to insert a pet cock on top of the cylinder near the hand crank end and leave this pet cock open to avoid forming a vacuum in back of the piston.

Hard running registers cause meters to lose sensibility, hence loss of registration on small flows; cause the pointers or hands to become somewhat out of position making reading of the meter difficult; cause spur gears to be stripped from their spindle fastenings, hence no registration; cause change gears to be stripped and broken off from their spindles, hence no registration; cause stuffing boxes to become leaky more quickly; and cause general wear throughout the meter. Cleaning and repairing of corroded registers is costly, and thousands of registers have had to be discarded because of corrosion.

The all-around saving due to our greasing meter registers is difficult to measure in dollars and cents; however it is safe to say that the saving is considerable.

Register Box Screw Seal

Sealing of the water meter register box has been debated on various occasions. The direct reason, of course, for sealing the register box is to indicate to the consumer or other interested parties that only those persons having authority to do so shall break the seal and remove the register box, thus preventing unauthorized persons from tampering with the meter register or "change gears."

The sealing device must therefore be positive and complete, to the extent that it will have to be broken or destroyed before the register box can be removed; and it should convey the impression that it must not be tampered with or duplicated. However, the seal should not be cumbersome or too difficult to install or remove, but should be convenient for ready use in connection with routine meter repairs in the field.

Embodiment of all these features has been accomplished in the register box screw seal shown in fig. 5, which has proven fully sufficient for our purpose.

Our register box screws have a threaded hole passing through the head of the screw under and directly in line with the screw-driver slot. The register box screw seal is made of 80 per cent lead and 20 per cent antimony (for breaking purposes), and spans the head of the register box screw and loosely contacts the side of the register box.

The seal is held on to the head of the register box screw by

a threaded brass pin passing through a hole in the side of the seal and then screwing into and through the threaded hole in the register box screw. This pin is machined to break off flush with the outside face of the seal. The pin passing through the seal and screwing into the register box screw cannot be extracted to remove the seal

FIG. 5. REGISTER BOX SCREW SEAL

from the register box screw; and contact of the seal with the side of the register box prevents removal of the register box screw without breaking the seal. The register box screw can be used again.

The department purchases super-diamond rolled steel floor plate for the making of steel meter box covers (fig. 6) for meters housed in concrete wells installed in driveways. Steel plates are used to

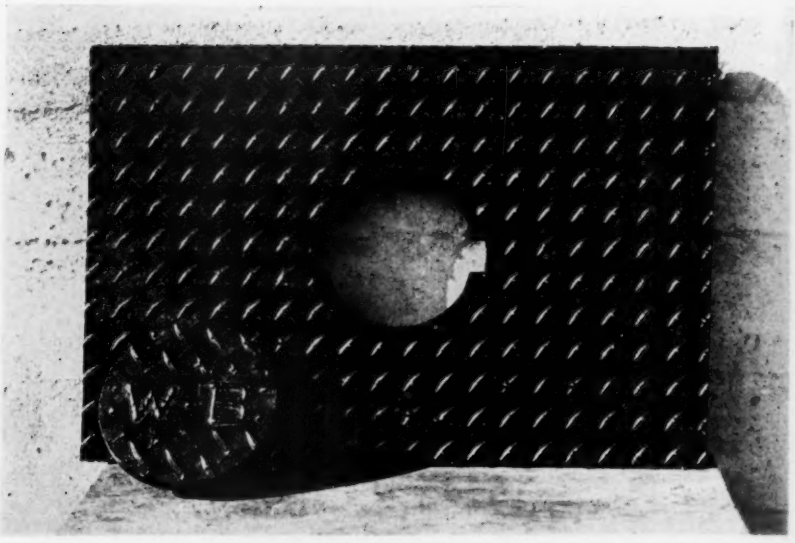

FIG. 6. STEEL METER BOX COVER

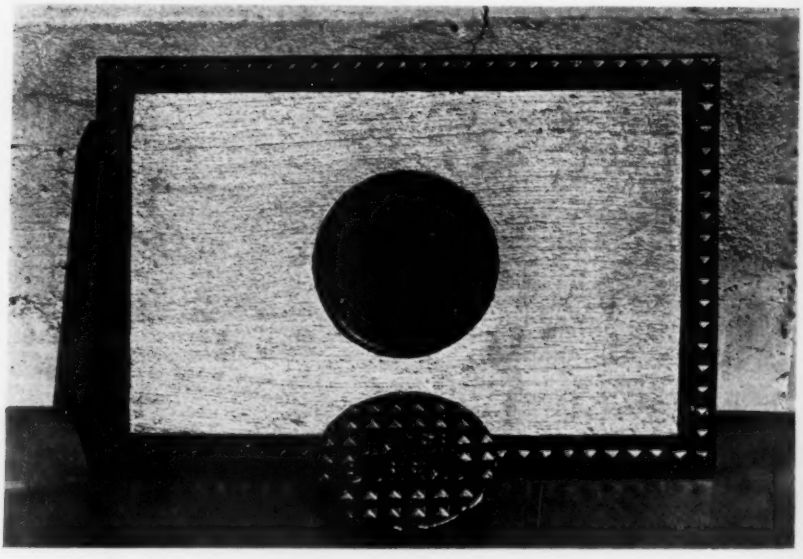

FIG. 7. CAST IRON FRAME, CONCRETE-FILL, METER BOX COVER

cover meter wells in driveways for the reason that they will withstand far greater weight and sudden jar due to trucks, etc., than would a cast-iron cover of like weight and size.

As this steel is not hard, the diamonds become smooth from wear and are then dangerous to pedestrians, especially where plates are placed in sloping driveways. To eliminate the replacement of these plates due to wear, and also to lessen the danger from pedestrians slipping on them, the department uses an electrode of steel very much harder than the plate itself and electrically welds on every other diamond a small drop of this steel. These plates are equipped with a round centerpiece of steel which is removed for reading the meter and when in place locks with lugs.

Cast-Iron Frame, Concrete Fill, Meter Box Covers

Because the diamonds on cast-iron meter box plates become smooth and dangerous from wear, the department has frames of cast iron made and fills these frames with reinforced concrete having a rough surface as shown in fig. 7.

This method of housing meters eliminates the necessity of discarding cast-iron plates and greatly lessens the danger from slipping on them, especially on sloping sidewalks. These plates are equipped with a round centerpiece of cast iron which locks with lugs and is removable for reading the meter.

Better Meter Box Covers

The frequency with which children and other unauthorized persons remove centerpieces in concrete meter boxes, creating a hazard for pedestrians, and a liability to the department; made it necessary to design a concrete cover with a cast-iron ring, or seat for its centerpiece, cast integrally with the concrete meter box. This ring, or seat, has two slots and four stops, and the centerpiece has two lugs which drop through these slots. By a one-quarter turn the lugs on the centerpiece come in contact with the stops on the ring, or seat, and lock the centerpiece. The risk of the centerpiece being carelessly removed is reduced by the necessity of turning the centerpiece before it can be lifted out, which can be readily done with a key fitting into two circular holes in the centerpiece for removing it to read the meter.

It is now the intention of the department to use meter boxes of this type to house meters set in parkway lawns, and the meter boxes

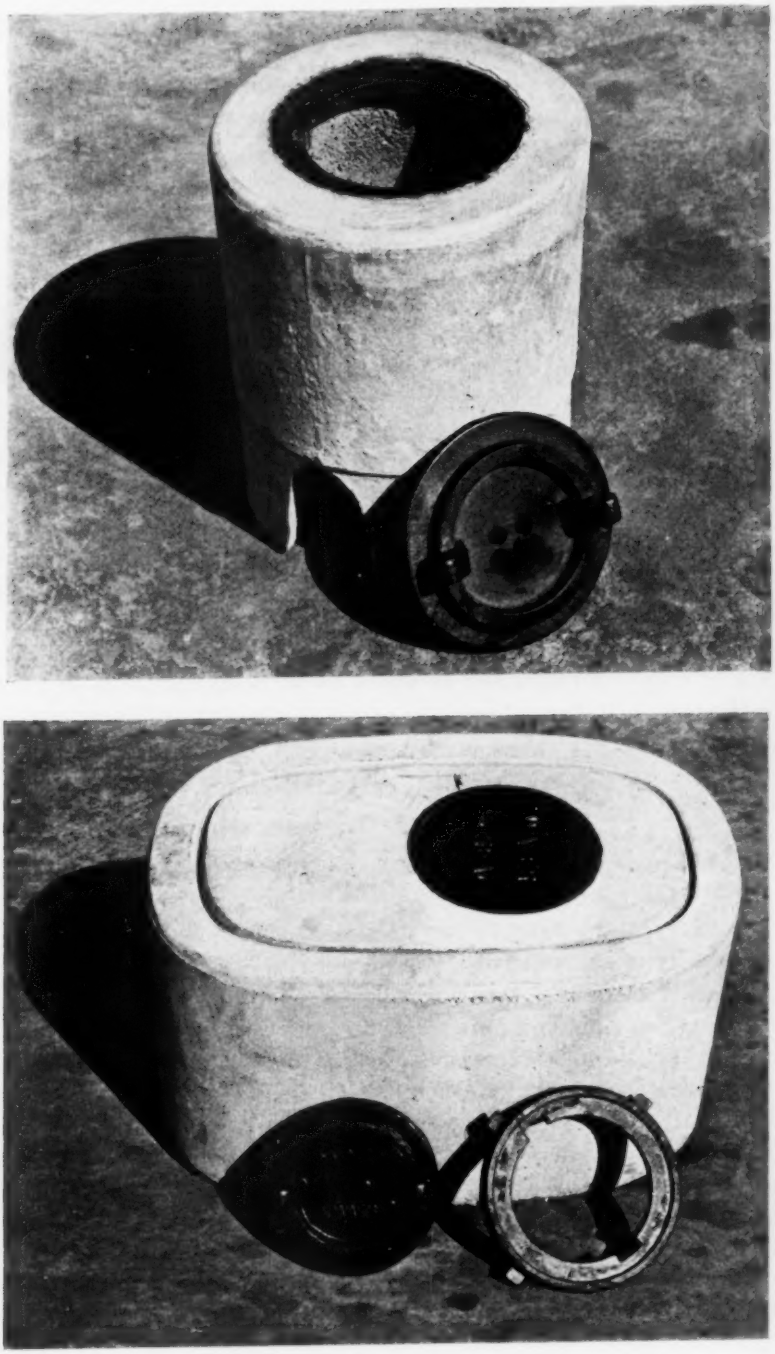

FIG. 8. IMPROVED CONCRETE METER BOXES AND COVERS

are to be large enough to change the meter inside the box by removing the whole cover. In fig. 8 are shown examples of meter boxes and covers.

Flushing of sewers through flush tanks is considered necessary to rid the sewers of the accumulation of solids which cause trouble, especially near the head of sewers with slight grade.

As a large volume is necessary per flush for proper flushing, the flush tanks are designed to discharge automatically when approximately 300 gallons of water has accumulated in the tank. As one flush per day is required, the jet meter is calibrated according to the

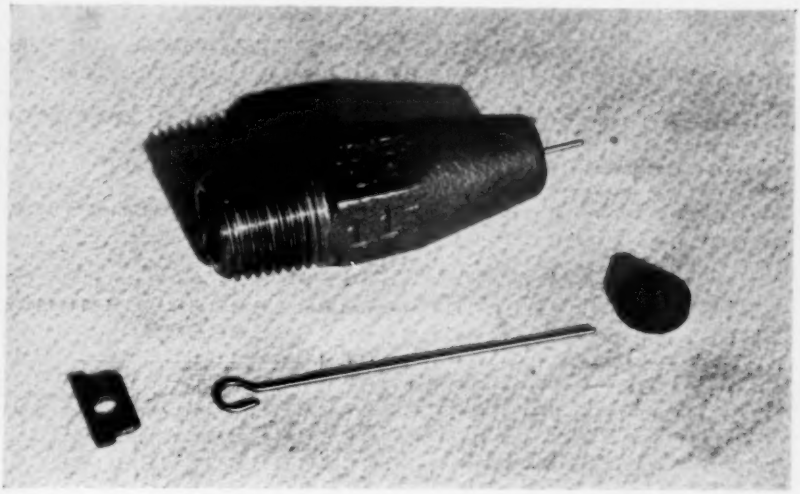

FIG. 9. JET METER FOR AUTOMATIC SEWER FLUSHING

prevailing water pressure to deliver into the tank 300 gallons in 24 hours, as nearly as possible.

Several types of jet meters have been tried to find one that will meet this requirement, and some of them have been quite expensive. The common trouble with all of them has been the clogging of the discharge orifice by algae growth and corrosion, hence the required amount of water per flush was not delivered into the tank in the proper time.

The jet meter developed by this department is much more dependable, costs less to make, and its maintenance cost is far less, than any other type used in the past. We now have 6,000 in service and are installing more. This meter is shown in fig. 9

This jet meter is composed of a bronze body having a composition of 84.5 to 86.5 per cent copper, 6 to 8 per cent zinc, and 3.5 to 4.5 per cent lead and tin. It is $2\frac{5}{16}$ in. in length and weighs 3.7 oz. The inlet end of the body has a male standard $\frac{1}{2}$-inch pipe thread which is slotted for the retaining of a strip of stainless steel containing a central hole. A stainless steel wire is freely hung from this hole and extends downward through a round hole in a disk of hard rubber or stainless steel seated in the lower part of the body. The standard size hole in the disk is .0625 of an inch in diameter, hence the opening through which the water flows is the annular space around the wire. To obtain the desired discharge under the varied water pressures in our system, different sizes of wire and drills are used. In table 1 are shown specific pressures and their corresponding wire size and drill size.

TABLE 1

Combinations for Jet Meter to Deliver 300 gal. per 24 hr.

WATER PRESSURE	WIRE DIAMETER IN INCHES	DRILL SIZE
40 lb.	.0455	#53
60 lb.	.050	#52
80 lb.	.049	#53
90 lb.	.0455	#54

The jet meter is installed in a vertical position to allow the wire to vibrate freely, thus tending to prevent algae growth from clogging the annular space around the wire. The wire extends only far enough through the disk to be gripped with the fingers for freeing in case of clogging, and to prevent the wire from being bent when handling.

Although we still experience some slight corrosion trouble with this jet meter, this disturbing element has been reduced to a minimum. The maintenance cost is extremely low, due primarily to simplicity of construction and efficiency of the meter.

These examples of improvements in standard equipment by redesigning the old, and of developing new devices and new equipment, are the result of considerable research and of over 35 years' experience by men in our department who have been able not only to recognize a deficiency in a particular piece of machinery or equipment, or the definite need of a new product, but who have also been able to analyse existing troubles and find an effective remedy for them.

Rate of Flow Register

By F. S. Brainard

THE Meter-Master was developed in Hartford, Connecticut, and it has become an indispensable part of our equipment. It has been my duty, as distribution engineer, to endeavor to satisfy some of the complaints of our customers and, as in all other water departments, many of these complaints were that the water bill was larger than usual. We used to follow the usual procedure: we listened to the complaint, tested the meter, inspected the plumbing and then tried to convince the customer that the bill was just. However, in a large proportion of the cases the customer was not satisfied as we had nothing to show the use of the water, other than the reading of the meter backed by a test showing it to be registering correctly. In a great many cases the customer paid the bill and left the office with the impression that he had been made to pay for something not received and he was not slow in passing this information along to his friends, many times magnifying the grievance.

The result of this method of handling high bill complaints is to make worse the poor opinion held of most water departments by the general public, for the public is inclined to believe that water departments are very arbitrary and unjust, charging for water they think could not have been used. The elimination, as far as possible, of this antagonism toward water departments seems to me to be one of the important projects which is needed in the water works field, as it is not possible for any business to function at its highest efficiency without the full support of the public. We are trying to improve our public relations in Hartford by using the Meter-Master* on most of the high bill complaints and have found it successful in most cases.

A paper presented at the New Jersey Section meeting at Asbury Park, N. J., October 21, 1938, by F. S. Brainard, Distrib. Eng., Hartford Water Bureau, Hartford, Conn.

*Hereinafter known as the rate of flow register.

The complaining customers are usually of the opinion that you are trying to help them when you come around in the morning and tell them the people in the house went to bed the night before at 11:30 and arose at 6:45 this morning. You may also notice that some one flushed the toilet at 2:10 A.M. While this may be embarrassing to the lady of the house, she knows these things are true and, therefore, believes you when told there is a leak somewhere in the house that is using water at the rate of two cubic feet per hour, which if allowed to go for six months will amount to 8,736 cubic feet and will cost $13.10 in addition to the usual bill of $8.00. When the leaky toilet is pointed out to her, she is thankful to you and is satisfied with the explanation of the trouble.

We had a case of an apartment house where there was a very large increase in the consumption and when we notified them of the condition they claimed the meter must be wrong, and, as usual, wanted it tested. We called at the apartment and asked the janitor if he was sure there were no toilets leaking. He informed us that it was impossible for any of the toilets in that building to leak as they were a special oil operated type of flushometer valve which could not leak. While this information, that there was any type of toilet that could not leak, was news to us, this argument was carried no further. The practice of our department is to get a record by means of the rate of flow register of the consumption before testing a meter on complaint.

Therefore, we told the janitor we would install this instrument on the meter and see what it would tell us. He seemed interested in the instrument and watched us install it during which time we explained what the record could be expected to show. This was about 10:00 o'clock in the morning.

The next morning we came back and took off the chart. The janitor was there and we let him inspect the chart and explained to him that the record showed a minimum use of about fifty cubic feet per hour both day and night with the exception of about two hours—between two and four in the afternoon of the previous day—at which time there was a noticeable decrease in the consumption. We told him we did not know what made that decrease and asked him if he had shut off anything in the building at that time. He informed us that he had shut off two toilets in one of the apartments about two in the afternoon, while the people were out, and had turned them on again about four o'clock so as to have them in working order when

they returned. This record convinced him that the trouble was in the toilets, which he had informed us could not leak. This janitor asked us to let the instrument stay on for a day or two as he was going to have a plumber go over the toilets and he wanted to see the results. This request was granted and the minimum night rate was reduced from fifty cubic feet per hour to less than five cubic feet per hour, which he said was good enough. The result was a satisfied customer who agreed that the trouble was not in the meter.

Another case of large consumption was investigated in a roadside diner where it was claimed a plumber had the day before checked all the plumbing fixtures and reported that there were no leaks. We looked over the various fixtures and they seemed to be in good condition. The rate of flow register was installed and we returned the following day to ascertain the amount of water used during the several periods of the day. The amount used was satisfactory with the exception of about two hours in the afternoon at which time there was a steady use of water recorded. The proprietor was sure no water was being used at that time. He assured us that no one had left a faucet open and expressed the opinion that the trouble was a defective meter which registered when no water was being used.

We then went to the various toilets and flushed them with the result that we found that the toilet in a rest room did not shut off after flushing and continued to run until it was flushed a second time. We also found the rate of use by this toilet was the same as the use recorded the day before when no water was being used. The evidence was so convincing to the owner of the Diner that he said several things (not too complimentary) about plumbers in general and the one who had inspected his property in particular. He also said he was satisfied that there was no trouble with the meter.

I could continue citing cases of this kind but I think these two instances illustrate how we let the customer convince himself that the water was used. This customer then has a much better opinion of the department and this procedure is much more satisfactory to us than it would have been under the old method.

We have about 417 meters, two-inch or larger in size, which constitute about $1\frac{1}{2}$ per cent of the total meters and last year produced nearly 14 per cent of our total revenue. Therefore, we believe it well worth while to give them a little special attention.

We make periodic tests of all larger sized meters as follows: 2-inch every 3 years, 3-inch every 2 years, 4-inch and larger, each year.

Before each periodic test a rate of flow record of consumption through the meter is taken for at least a twenty-four hour period. The meter test results are plotted and then compared with the rate record. With this information we are able to determine whether the meter is of proper size and type for efficient operation. This procedure has enabled us to lower capital and maintenance costs by substituting smaller sized meters where over-sized meters were found, and in nearly every case there has been an immediate increase in the revenue.

For example, in one six-story office building, housing a bank and numerous lawyers' offices, the observed maximum rate of flow was only thirty gallons per minute. When the 4-inch disc meter was replaced with a 1½-inch disc meter, the consumption jumped from 4,700 cubic feet per month to 7,000 cu. ft. per month. Also, when the 3-inch disc meter serving a thirty-two family tenement house was reduced to 1½-inch, the consumption jumped from 29,000 cu. ft. per month to 36,500 cu. ft. per month. Thirty-nine premises where such changes were made showed a total increase in revenue for water at the rate of $2,300 per year plus the saving in capital investment and lessened maintenance costs.

We also use the rate of flow register in connection with the pitot-meter survey we make of our system each year, feeding some of the smaller districts through metered connections, around a closed gate and obtaining a twenty-four hour record of this meter. There are also numerous occasions when it is desired to obtain information relative to rates and quantities of use over short periods of time, where the rate of flow register works in very satisfactorily. It gives a permanent record for future reference and does away with the human element which is sometimes unreliable. Use of the rate of flow register is more economical than stationing a man to read a meter every minute for several hours during the night.

To repeat the statement made near the beginning of my remarks: we find the rate of flow register indispensable in Hartford.

Watershed Yields

By J. D. Carpenter

THE question of watershed yields is one which has been of primary importance to all persons connected with water works operation. In the olden days in many cases the low water flow of the stream was considered the yield of the watershed. Later as necessity required, storage was built and the yield of the watershed was increased by storing some of the spring run-off for release during the drier seasons.

Later the State and a few private corporations established stream flow measuring stations where gages were installed on a bridge pier or abutment, or some suitable place, and readings of the water level taken once or at the most twice a day. Rating curves were established, to convert the gage height readings into volume of discharge. These rating curves were checked as frequently as the limited finances would allow, but were often found to be in error because of the changing condition of the river bed, or because of equipment inaccuracies, or other reasons.

In this same manner, but probably with more accuracy and in more numerous locations, the rainfall in the eastern part of the United States has been recorded. In the past this was done with the old-fashioned rainfall gage where the depth of precipitation was measured after each rain.

In most locations these records are available for the last 50 years and in this period the driest 5 years are those which we have just passed through, from 1930 to 1934 inclusive.

Today, however, in Pennsylvania there have been established approximately 100 automatic recording stream flow stations which are placed at locations which are considered both strategic and

A paper presented at the Four States Section meeting, Washington, D. C., October 7, 1938, by J. D. Carpenter, of Gannett, Eastman & Fleming, Inc., Harrisburg, Pa.

reasonably permanent so that the rating curve of the stream when once established should not vary much from year to year. These gages are operated with a heavy weight like the old-fashioned grandfathers clock and can go without attention for from one to three months or more, depending upon the depth of the well at the gaging station. They are located on areas from 26,000 square miles down to 9 square miles.

Also, the Department of Forests and Waters of the State of Pennsylvania, in conjunction with the United States Weather Bureau and the United States Geological Survey, has established certain regulations for their operators whereby at critical times, that is when the rainfall or stream flow exceeds certain definite limits, the operator in the field will report by telegraph four times each day into a central receiving station in Harrisburg. These particular regulations are primarily for the use of flood prediction.

Automatic Wireless Gaging Stations

The State is also considering a plan by which high frequency waves would be used to relay the water level reading automatically into a central receiving station in Harrisburg. Storage batteries would supply the energy at each gaging station, these batteries to be kept charged automatically by self-starting and stopping gasoline engines. With this plan, the reports from the different stations would come in whether or not an operator was at the station. This service would be entirely independent of telegraph, telephone or the established radio stations.

The State has also established in the last few years between 80 and 90 recording rain gages located very uniformly over the State. These gages will take care of 8 inches of rain in a single storm. The penpoint showing the rainfall is controlled or actuated by the weight of the water entering the gage. In the wintertime the receiving bucket inside the gage is partly filled with a dense brine solution, the zero point of the gage adjusted accordingly, and in this way all snow entering the gage is turned into water and its weight and time of precipitation accurately recorded.

In the eastern United States the annual rainfall usually averages between 30 and 60 inches. The relation of run-off to rainfall is a most important, but variable factor, dependent upon many surface and underground conditions; but in general where the rainfall is between 40 and 45 inches the run-off will be approximately 50 per

cent of the rainfall, the other 50 per cent being lost through evaporation, transpiration, underground seepage, etc. There are so many variables, however, that no general rules can be established.

In limestone areas, underground waters originating on one watershed may come to the surface on an adjoining watershed to the detriment of one stream and the benefit of the other, while with sandy or open subsoil conditions, a portion of the run-off may be flowing slowly under the surface of the ground.

In some states the government has taken over the control of all streams not now in use, and is making a charge for all water it relinquishes to other parties. This charge in Pennsylvania runs from $.10 to $1.00 per million gallons of water used, the $.10 rate being applied where the proposed user completely develops the stream with large storage, while the higher rate is charged to the user who makes a minimum development or use of the stream.

The records now being obtained, particularly in Pennsylvania, are accurate to within 2 or 3 per cent and if funds are available for their continued operation there will soon be collected reliable data covering the entire state.

At the present time, if the run-off of a watershed must be determined, the customary method of procedure is to collect all rainfall data within a radius of 30 or 40 miles, or more, depending upon the size of the stream, and with this data to prepare an average isohyetal or rainfall contour map from which is determined the average rainfall on the watershed in question. With these data a reasonably close approximation of yield can be made.

Comparable Stream for Closer Estimate

Next, the stream gaging records of the state should be examined to find some stream on which flow measurements have been taken and which has as nearly as possible the same physical characteristics and rainfall as the stream being measured. By comparing the two drainage areas a still closer estimate of the flow from the drainage area in question can be made.

The final step in determining the watershed yield would be to establish on the watershed one or more rainfall gages, if this has not already been done, and to establish an automatic water level recording gage on the stream as close as possible to the location being considered. The rainfall gage will cost about $100 complete, while the water level recording gage with the fireproof house and

necessary equipment will cost between $750 and $1,000. There are some, however, which cost over $2,000. As soon as records begin to be available from these gages they can be compared with those of somewhat similar streams on which the record of past years is available. The final and most satisfactory knowledge is, of course, a continuous record of the stream in question at the location under consideration.

In one instance in Pennsylvania where almost complete storage was built, a watershed of 8½ square miles was estimated in 1930 to yield about 12,000,000 gallons per day. However, after the dry period which extended from 1930 to 1936 in Pennsylvania the estimate of the controlled dry weather flow was reduced to a little over 10,000,000 gallons per day for the 8½ square miles of watershed. This watershed is now developed and during the past two years has yielded about 10,000,000 gallons per day, or over 1,000,000 gallons per day per square mile.

The City of Harrisburg is now studying a watershed of 21½ square miles and finds the average flow over the last 30 years to have been 21,500,000 gallons per day or 1,000,000 gallons per day per square mile of drainage area, with a rainfall of between 43 and 44 inches. With a storage of 7,000,000,000 gallons this stream will yield approximately 17,000,000 gallons per day or about 800,000 gallons per day per mile of watershed.

As the period of record grows longer and the record itself is made more accurate, average and minimum yields from our different types of watersheds will become more accurately known and water supply men will not be caught unprepared as many of us were in 1930.

ABSTRACTS OF WATER WORKS LITERATURE

Key. 30: 402 (Mar. '38) indicates volume 30, page 402, issue dated March 1938. If the publication is paged by issues, **30:** 3: 402 (Mar. '38) indicates volume 30, number 3, page 402. Material inclosed in brackets, [ ], is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British).*

ADMINISTRATION AND PERSONNEL

Municipalities and the Federal Income Tax. AUSTIN J. TOBIN. Illinois Munic. Rev. **17:** 237 (Dec. '38). **The Water Works Industry is Vitally Interested in the Federal Tax Threat.** CHARLES J. MCLAUGHLIN. W. W. Eng. **91:** 1362 (Oct. 12, '38). Alarmed by decision of U. S. Supreme Court on May 23, '38 (*Helvering* v. *Gerhardt*) that employees of Port Authority of New York were subject to federal income tax, the attorney generals of 39 states, together with representatives of other public agencies throughout the U. S. organized the Conference on State Defense to defend states and cities and their employees from the implications not merely of the decision but also, and more particularly, from the U. S. Treasury Department's embarkation on a program of federal taxation of state and city bonds and even of the revenues of the states and their minor civil divisions. Moreover, within a day of the decision noted "*it was realized that all state, county and municipal employees were liable to the danger of 12 year's retroactive taxation.*" On June 24, '38, Dept. of Justice sent to the Treasury Dept. a report on "The Immunity Rule and the Sixteenth Amendment" claiming that Congress has the *power* to pass an act taxing salaries of all state and municipal employees, past and future, and all state and municipal bonds, outstanding and future. The report did not directly state that the federal government can tax state and municipal revenues, but it held that the federal government has "supreme" taxing power. Thus it became clear, that the government was after "bigger game" than the relatively small revenue from taxes on salaries of public employees. As proof, Tobin says the Treasury Dept. is attempting to collect over $50,000 in taxes on outstanding bonds of the Delaware River Joint Commission. If it can do this it can also levy on revenues of municipal rapid transit, power and light, port and harbor, toll bridge, water supply, drainage, sanitation, hospital, flood control, park and all other revenue-producing state and municipal services. To meet the threats thus presented the Conference on State Defense has two major objectives: (1) "To oppose any attempt to add to the cost of state and municipal

government by federal taxation without first securing the consent of the states through a constitutional amendment guaranteeing the reciprocal right to tax future issues of federal securities in the state, and prohibiting absolutely any federal taxation of the revenues and outstanding securities of the states, their subdivisions and agencies." (2) "To secure the passage of an Act of Congress at the '39 session to prevent the retroactive application of any federal tax upon employees of the states and their municipalities." Co-operation is being given by the American Municipal Assn., State Municipal Leagues, Municipal Finance Assn., American Federation of State, County and Municipal Engineers, International Associations of Fire Fighters and Police Chiefs, and by Senators, Congressmen, Mayors, Comptrollers, Treasurers and others. Central headquarters of the Conference are at 111 Eighth Ave., N. Y. City, and at offices of State Attorney Generals. Tobin holds that the old governing theory of state sovereignty should be continued to exempt state and municipal bonds from federal taxation; that if such bonds are taxed a material interest rise will follow. Federal taxation of state and municipal revenues would strike at the heart of state sovereignty; would completely centralize all power in the federal government; would make public ownership of public utilities practically impossible; and would destroy self-liquidating public agencies, depriving the people of the states of badly needed facilities. If salaries of all state and local officials were subjected to the federal income tax they would need to be increased to make up for their virtual lowering due to immunity from federal taxation. Finally, Tobin urged municipal employees to see or write their Congressmen to support legislation necessary to protect themselves and the cities they serve. The McLaughlin article in W. W. Eng. of Oct. 12 is directly addressed to water works men. The declaration of the U. S. Supreme Court on March 15, '37 (*Brush* v. *Commissioner*, 300 U. S. 352) that owning and operating water works is a municipal function and therefore that water works salaries are exempt from federal income tax seemed to have ended the threat to municipal water works; and standing alone it would seem to negative the recent threats (outlined above). But only 5 of the 9 judges agreed in the decision that the salary of W. W. Brush was exempt; 2 concurred but only because of a previously unchallenged Treasury decision; 2 flatly dissented. Meanwhile 2 of the 5 justices have resigned and been replaced. Now comes the *Helvering* v. *Gerhardt* decision in which 4 of the 7 justices then sitting voted against the position of the majority in the Brush case. This later decision holds that a governmental function is not immune unless "indispensable" "to the continual existence of state governments as such." This rule, the courts says, holds for revenues, interest on bonds and salaries. After further analysis of the later decision, in which the court apparently curtailed the implications of the court in the Brush case, McLaughlin states that the Brush decision has become a slender reed for water works officials as regards both salaries and revenues, and declares: "In my opinion, they should rather consider the Gerhardt decision and attempt to decide their status under that later ruling of the Court." Farther on, McLaughlin states that prominent officials declare that ruin to their water works would follow taxation of their revenues or at least defeat the ends of municipal operation. As to federal taxation of water bonds, that would increase interest rates 1 to 2%.

He does not argue for exemption of securities but says that if it is to come "some way must be found which will prevent its being done completely at the expense of the states and municipalities solely for the advantage of the federal government." Finally he urges water works managers to bring the situation confronting them to the attention of their Senators and representatives, and among other elements of protection that legislation be enacted against retroactive taxation of salaries. [The upsetting in '37 of the rule that water works is not a municipal function, long held by doctrinaire legalists, and supported in the lower federal courts in the Brush case, was refreshing. Apparently, the Supreme Court has not reversed itself in the Gerhardt case but has raised sky-high the taxing powers of the federal government. The situation thus created makes more imperative than ever a study of the basic principles of taxation, with close attention to avoidance of tax duplication, triplication or worse. If the United States is to tax revenues from all municipal utilities, the rate structures and accounting of all water works should be scrutinized and in many cases reformed without delay. Two things are obvious: only net income can be taxed, so that must be determined beyond dispute; and water consumers should not be charged high rates to provide revenue to reduce the general tax rate.]—*M. N. Baker.*

St. Paul's Adjustable Salary Scale for City Employees. SAMUEL E. TURNER, JR. Nat. Munic. Rev. **28:** 583 (Dec. '38). Salaries of 1,800 employees at St. Paul have for 16 yrs. been adjusted to changes in living costs. Agreement to the plan made in '15 after study of duties and service history of every employee. Subsequently Civil Service Bureau established standard titles, grades, minimum and maximum rates of pay for clerical services, which were adopted by city council. In '18 a uniform salary schedule was adopted by some of the commissioners (under commission plan of government). In '22 a more comprehensive plan was adopted, including cost-of-living standard. A temporary setback occurred in '32, when a group of employees convinced the council that no downward adjustment should be made, but on June 1, '32 the cost-of-living standard was re-instated because of heavy tax delinquencies. Percentage increases on certain basic entrance salaries since '16 have been: Oct. '22, 50%; July '24, 52%; Jan '27, 53%; Jan. '28, 50%; Jan. '31, 47%; June '32, 38%; Jan. '33, 28%; Jan. '36, 31%; Jan. '37, 35%; Feb. '38, 39%.—*M. N. Baker.*

Making the Merit System Work. LYMAN S. MOORE. Public Management. **20:** 325 (Nov. '38). As result of discussion at meeting of the Civil Service Assembly at Washington the gathering, composed of public personnel administrators, rejected proposal to have competence for public service certified by a private group and voted in favor of establishing professional standards for voluntary acceptance by public agencies. Action was based on report of the Assembly's Committee on Professional Standards which had been directed to prepare standards and procedure for certification by the Assembly of three grades of competence in the personnel field. Louis Brownlow compared certification by English "Guilds of technicians" with American certification by state agencies and held that (Moore's language) "for a professional organi-

zation to establish standards and attempt to impose certificated members on the public service would be merely to extend the system of 'preferences' to which all merit system supporters must be opposed." James M. Mitchell, manager of personnel service for the Michigan Municipal League, said that his agency was prepared to render full personnel service for $7 per employee for the first hundred employees, $5 for the second hundred and $3 for each additional employee. For preparing and scoring an examination a flat fee of $25, plus $1 per applicant is charged. Clifford N. Amsden, secretary of the Los Angeles County Civil Service Commission, said that the figures just given are close to those charged by his organization to small cities in the Los Angeles area.—*M. N. Baker.*

Qualifying Examinations Under Proposed Merit System. ANON. Citizens' Business (Phila. Bur. Mun. Res.) (Nov. 29, '38). Under plan proposed by the Philadelphia Charter Commission the 15,681 city-county employees would have to pass a qualifying examination in order to remain in service. If these examinations were properly designed and administered all competent employees could readily gain permanent status. Two states that established state-wide merit systems in '37, Maine and Michigan, prescribed this system. The Philadelphia Charter Commission chose qualifying rather than (1) "covering in," under which existing employees without civil service status would be given permanent status automatically and (2) "provisional status," under which existing employees would continue in service only until their positions were filled from eligible lists established by competitive examinations.—*M. N. Baker.*

The Human Element of Public Relations. MENTOR HETZER. W. W. and Sew. **85:** 191 (Mar. '38). Vital to good public relations are employees who are neat, friendly, alert and interested in the customer.—*H. E. Hudson, Jr.*

Explanation of Regulations Governing Water and Sewage Treatment Plant Operators. F. D. STEWART. Ann. Rept. Ohio Conf. Water Purif. **17:** 9 ('37). Regulations adopted by Public Health Council, effective Aug. 1, '37, are given and discussed. Enactment of specific state law not necessary as statutory authority for State Dept. of Health to adopt such regulations was covered by existing legislation. Regulations are specific in regard to individuals under whose supervision treatment plants are placed and they will be extended to operating personnel whose duties may include responsible charge for any period of time. One clause gives Director of Health authority to fix classification of an operator at any plant, which virtually results in classification of plants. It is believed that plan is workable, fair to operator, beneficial to him and his profession and advantageous to municipality.—*R. E. Thompson.*

The Chemist at Work. J. Chem. Ed. **15:** 228 (May '38). *The Chemist in the Water Resources Laboratory.* MARGARET D. FOSTER. The writer's work in the Water Resources Lab. of the U. S. Geol. Survey consists of water analysis, geochemical interpretation of water analysis, and modification of old or development of new methods of analysis. One chemist usually does all work

on a given project, including geochemical interpretation in consultation with staff geologists, and thus routine analytical work becomes more interesting. In development of analytical methods, work on detn. of fluoride by effect on ferric thiocyanate color is cited. Prospective water resources chemist should be well grounded in inorganic, quantitative and physical chemistry. Most chemists now in the laboratory came with only a bachelor's degree, though some have since taken higher degrees. All must undergo specialized training in methods used in the Water Resources Lab. Personal characteristics desired include sense of fairness and cooperation, good nature, even temper, neatness, quickness, efficiency, and scientific viewpoint. *The Railway Water Chemist.* R. C. BARDWELL. *Ibid.* p. 236. In testing dept. lab. of railway, time can be sacrificed for accuracy; all work is done in lab. itself. In water dept. lab., most important factor is prompt and proper application of chemical results to current operating conditions; much field work is necessary. "Standard Methods" followed for complete analyses but short-cuts used for routine tests. Most analytical work volumetric. Besides analysis of water, treatment chemicals must be checked regularly. The railway water chemist spends the greater part of time on road visiting outlying water stations and checking locomotive boiler operation, e.g., making concn. pick-up tests on an operating locomotive over period of several days. He benefits by understanding of bacteriology, engineering, mechanics and hydraulics. Must be able to keep records and files and write reports intelligible to men not technically trained. Desirable personal traits include ability to work well with fellow employees (including those in operating service), honesty, initiative, resourcefulness and diligence, all backed by plain common sense. Railroad water chemistry is not a rapidly expanding branch of the profession, though noticeably more men employed in the field than 20 yrs. ago. In '35 there were approx. 100 positions of this character in U. S. Starting salaries not high and advancement is seldom rapid, though it depends on the individual and his ability to take advantage of opportunities as they arise. *Sanitary Chemistry as a Vocation.* EDWARD S. HOPKINS. *Ibid.* p. 371 (Aug. '38). Chemistry in sanitation includes water purification, sewage disposal, and trade waste treatment. "The object of water purification is to produce a commodity having a palatable taste, without odor, taste, turbidity, and free from disease organisms." Treatment intended to produce these results must be controlled by chemical, physical and bacteriological tests. Raw sewage may be discharged directly into stream or various treatment methods may be used, requiring control tests such as biochemical oxygen demand, methylene blue stability, suspended solids, etc. Trade waste disposal is a large field in which many problems can be solved only by cooperative lab. research by industry and sanitary authorities concerned, frequently leading to changed mfg. processes and by-product recovery. The sanitary chemist and bacteriologist should keep continuously abreast of their fields. Undergraduate college training usually satisfactory background but needs supplementing for special work. Chemical engineering knowledge acquired through experience or through formal courses is fundamental in plant control. "A present outstanding handicap of the science is lack of chemical advice or training in design of many existing plants," though this is being eliminated in present-day design. At-

tention directed to the comprehensive report covering details of training for water and sewage plant operators, (Ind. Eng. Chem.-News Ed. **12**: 389 ('34)), to which author would add training in analytical chemistry. [Brief biographical sketch of author precedes each article.]—*Selma Gottlieb.*

Frequency and Duration of Disabilities Causing Absence from Work Among the Employees of a Public Utility, 1933–37. WILLIAM M. GAFAFER AND ELIZABETH S. FRASIER. U. S. Pub. Hlth. Repts. **53**: 1273 (July. 29, '38). Fourth paper on disability absences of one day or more among male and female employees of Boston Edison Co. during five years. In '13 company inaugurated disability payment plan. During second 6 mo. membership an employee is allowed accumulated sick leave of 1 day per mo. at full pay. After 1 yr., full pay for continuous disability allowed for 15 weeks; beyond this, $\frac{3}{4}$ to $\frac{1}{4}$ of wages are paid for period depending on number of years of employment, closing with 372d day. For 5-yr. period there were 17,628 absences, causing 133,022 days of disability, yielded by 12,969 male and 3,272 female person-years of life in the company. Although frequency of all disabilities showed no decline from year to year, average days per absence showed downward trend. Frequency of absences from all disabilities was 900 per 1,000 males, with average of 7.5 days per male per year; for females, 1,820.3 and 10.9. Average number days lost per absence, 8.4 for males, 6 for females. Influenza and grippe rank first and account for about 15.5% of total days disability among both males and females. Highest accident rate for males was among linesmen, meter readers and repairmen; females, office cleaners and clerks lower than stenographers, etc. Industrial accidents among males show decidedly downward time trend and for non-industrial, slight downward trend.—*M. N. Baker.*

Fundamentals of Safety for the Chemical Worker. G. M. BRIGGS. Ind. Eng. Chem. **30**: 641 (Jun. '38). In 305 chemical plants having 121,504 workers, National Safety Council Records for '36 showed that operators of machinery and chemical apparatus were involved in 28% of all serious accidents. Repair and maintenance men had almost as many, followed by laborers, technicians and supervisors. Machinery involved in $\frac{1}{3}$ of all cases, presses, pumps, compressors and fans figuring most frequently. Employees injured when caught in or between objects accounted for half the total. Most important mechanical cause of serious injuries was faulty piling or arrangement of objects and materials, e.g., bags of heavy materials, piles of pipes, etc. Wrong attitude or lack of knowledge or skill of employees were principal personal causes of serious injuries. Safety education must begin when new employee joins organization and should be emphasized throughout his employment. Employee must be willing to learn safest practices, to follow prescribed safety rules in plant, and to be consciously aware of human factor in accident causation. New employee must be carefully instructed about his work-place and take time to become familiar with it. At beginning of his shift, worker should satisfy himself that operating and control equipment he is about to use is functioning properly. Protective equipment, e.g., goggles, rubber gloves, aprons, boots, gas masks and fire blankets should be kept in safe and proper

place, and in usable condition. Worker must be carefully instructed as to how to proceed in fire and other emergencies, must refrain from joking and horseplay, and assume definite responsibilities toward fellow workers.—*Selma Gottlieb.*

WATER SUPPLIES—GENERAL

Certain Characteristics of New Hampshire Public Water Supplies. CHARLES D. HOWARD. N. H. Hlth. News **16:** 4: 1 (Apr. '38). Most notable characteristic of the public water supplies of New Hampshire is the exceptional softness of the waters, a fact due to the generally predominating granite origin of its soils. More than 90% of the public supplies have a hardness under 50 p.p.m., and more than 70% are less than 20 p.p.m. Because of the extreme softness and a relatively high carbon dioxide content in the case of ground sources, the waters exert aggressive action upon pipe metals. This is particularly true for lead and for any substantial length of copper pipe. The pH of the water is below 7.0 for a majority of New Hampshire sources, requiring addition of a small dose of alkali in order that undue corrosion of the service pipe may be avoided. The hardness test of a water from any particular locality is used as an indicator to pollution, as ground water exposed to contaminating drainage will exhibit increased hardness. New Hampshire waters contain iron in varying amounts and the statement is made in the article that there is probably a greater field for iron removal treatments than there is for water softening devices. Table showing color, hardness and pH for a number of New Hampshire public water supplies accompanies the article.—*P. H. E. A.*

The Municipal Ground Water Supplies of North Dakota. G. A. ABBOTT AND F. W. VOEDISCH. N. Dak. Geol. Survey Bull. 11 ('38). Approx. 90% of State's pop. both urban and rural use water supplies from wells. Municipal supplies all have experienced difficulty during past 8 yrs. State may be roughly divided into 3 major ground water provinces (1) Red River Valley comprising flat plain formerly bed of glacial Lake Agassiz; (2) Drift Prairie occupying area between step-like rises of land between Red River and Mo. River, (3) the Mo. Plateau, that part of state west of Mo. Escarpment. In (1) water obtained from shallow wells in sand, gravel, clay and silt; and from deep wells where much of it is under pressure to provide artesian flows. Deep water highly mineralized. Areas of flowing wells with highly mineralized water common in (2), artesian wells and springs found in (3). Av. annual rainfall ranges from 20″ to 22″ in Red R. Valley to 12″–14″ in highest portion of Mo. slope in SW part of State. Av. annual pptn. for 1892–'36 inc. was 16.92″, wettest yr. '96—22.65″, driest yrs. '34–'36 with 9.51″ and 8.83″ respectively. Av. annual temp. 39.30°F., little variation in av. from yr. to yr., extremes within any one yr. great. In '36 max. 121° on July 6, min. −60°F. on Feb. 15, a range of 181° for '36, only 3 less than all time high of 184°. Evaporation av. 31.63″. Droughts common in midsummer. Problem requires extensive study and co-operation of all kinds of scientists. Of 295 incorporated towns investigated, 102 reported difficulty in securing water supplies and

54 towns actually hauled water for domestic use in '36. Type of water from each of water bearing strata given, as well as information of publicly owned supplies covering most of state.—*Martin E. Flentje.*

Water Resources of Washington. RICHARD GAINES TYLER. Bull. Univ. of Wash., Eng. Expt. Sta. Series Report No. 4 (Jun. '38). Bulletin is abstract of much more voluminous report on State's water resources and proposed plan of development prepared in cooperation with Nat'l Resources Comm. With 2.3% of area and 1.27% of total pop. of U. S., Washington has over 20.5% of national water power resources. Climate varies widely, ranging from sub-zero conditions of icy mts. to mid-summer heat of Eastern Wash. arid plains. Rainfall varies from 75'' near ocean and 30'' adjacent to Puget Sound to rates in excess of 200'' per yr. near summit of mt. ranges. In eastern part pptn. varies from 7'' to 50''. Municipal water supplies of State are, in general, of excellent quality and of ample quantity. Those west of the Cascades are usually soft and otherwise satisfactory. Supplies east of Cascades are harder, produce boiler scale and some require filtration. 50% of pop. supplied from surface sources, 19.6% from under-ground supplies, with 30.4% getting water from unknown sources. Of total pop., 1,124,031 (71.1%) served by municipal water supplies. Tabular data shows source of supplies, % of pop. served by each type (underground, surface, unknown), water supplies of principal cities with plant cap., and condensed information on all of State's municipal supplies. Information available on underground waters inadequate, however it is indicated larger part of populated area well supplied with underground water. Bull. contains number of tables, maps and diagrams giving information indicated in title.—*Martin E. Flentje.*

Annual Report of the Bureau of Sanitary Engineering, State Board of Health, Indiana—June 30, '37. B. A. POOLE. During the year the worst flood and one of the worst droughts in the state's history occurred. Typhoid death rate of 1.5 and infant diarrhea death rate of 9.5 is evidence of the success of protective measures in the emergency. Total of 885 investigations were made of the 303 public water supplies of which 33 are questionable and 6 unsafe. One supply contains significant amounts of fluorides. 806 stream pollution investigations made. Tabulations detail the results of the year's work.—*P. H. E. A.*

New York State Dept. of Health Annual Report, 1936. C. A. HOLMQUIST. A technical staff of 45 carries on the work of the Division through 15 district offices. Federal Aid is responsible, largely, for great strides in sanitary engineering works, there being under construction 41 water supplies costing $7,000,000 and 20 sewerage projects costing $52,500,000. When the unusually heavy ice jams in the Niagara River went out, a wave of pollution affected many plants, increasing the chlorine demand 10 times at one point. For the eighth consecutive year no water-borne typhoid epidemic occurred and the State death rate was 0.5 per 100,000. Three outbreaks of gastro-enteritis occurred in which the public water supplies were probably involved and several occurred at summer hotels using doubtful water sources. Tabulations show the work of the division for the year.—*P. H. E. A.*

Larger Water Supply Units in New York State. RUSSELL SUTER. W. W. Eng. **91**: 1232 (Sep. 14, '38). Economical solution water supply problems in N. Y. State requires joint effort of authorities in regions affected. Legal means not available for such action. Regions and possible methods of obtaining united action discussed.—*Martin E. Flentje.*

Water, Sewers and Services. L. B. ROBERTS. Eng. News-Rec. **121**: 375 (Sep. 22, '38). Design of utility systems for New York World's Fair described and discussed. All utility lines designed primarily to serve anticipated max. daily pop. of 800,000. Site to become part of city park system after termination of fair and distribution systems are therefore a compromise between permanent and temporary lines. Installation of asbestos-cement pipe permitted in certain areas where superimposed loads are light and where subsoil conditions provide uniform foundations. In other localities, c.i. or steel pipe is employed. Water for all purposes except display features, in which case recirculation equipment is mandatory, is taken directly from transmission mains of Catskill reservoir system. Max. hourly demand rate for sanitary purposes estimated at 12.5 m.g.d. and av. daily consumption at 2.5 m.g.d. Water for principal fountain displays will be obtained from lakes in fair area. Fountain displays will require nearly 100,000 g.p.m. All mains sterilized prior to use. In return for installation of permanent water mains and sewers by Fair Corporation, city supplies all water and provides for disposal of sewage.—*R. E. Thompson.*

Utilities for Millions of Visitors. ANON. Eng. News-Rec. **121**: 470 (Oct. 13, '38). Utility systems for Golden Gate Internat. Exposition are described. Fair site is island created in San Francisco Bay which will later be used as airport. Water supply, from San Francisco's city mains, is pumped across suspension spans of Bay Bridge through 10″ cement-lined, welded steel pipe to 3-mil. gal. reservoir excavated in rock on Yerba Buena Island. From latter, water flows by gravity to fair ground through 20″ pipe laid in connecting causeway. High-pressure system operates under static head of 110 lb. per sq. in. and maintains residual pressure of 100 lb. at hydrant outlets when supplying 20 fire streams of 250 g.p.m. For emergency purposes, connection provided to enable fire boat to pump salt water into high-pressure system at 175 lb. per sq. in. Domestic system, which also supplies water for irrigation, fountains and lagoons, will deliver av. of 1.8 and max. of 3.5 m.g.d. In this system also, for emergency use, provision has been made for flushing toilet fixtures with salt water should demand exceed supply. Water used for fountains will be filtered and recirculated. Main lagoon, of 7-mil. gals. capacity, is provided with two 6,000-g.p.m. circulating pumps and a 450-g.p.m. filter.—*R. E. Thompson.*

The Calcutta Filtered Water Supply. A. K. SEN. Indian med. Gaz. **72**: 488 ('37). Describes history of water supply of Calcutta from beginning of eighteenth century to present day. First works completed in 1869 and supplied pop. of 400,000. When present scheme is complete supply of 100 m.g.d. should be available. Present supply varies between 66 and 70 m.g.d. with allowance of 25 gal. per head per day. Water obtained from the river Hooghly

at Palta and treated by sedimentation and slow sand filtration without chlorination. Complaints recently received of brackishness. Hardness and salinity of the Hooghly near Calcutta and near Palta between Feb. and July are shown in table. Salinity increases until rains begin in June or July, when it drops sharply. In '35 and '36 salinity rose to higher figure than in '34 or '37 but even in '36 water at upper sampling point did not become sufficiently saline to taste brackish. In an investigation of the bacteriological quality of water at hydrants in the city, positive presumptive tests always obtained with 10 c.c. samples, and 65% of samples showed fecal bacilli in 10 c.c. As water leaving filtration plant gives negative presumptive tests in 10 c.c. samples, deterioration must occur at some point in the distribution system. This may be due to contamination at the reservoirs at Tallah, to aftergrowths, or to contamination from polluted ground water sucked into mains during periods of low pressure. No definite conclusions reached. Death rate from typhoid fever since '05 has increased many times more than the population. Reasons for this are discussed.—*W. P. R.*

Singapore Water Supply. Engineer's Review of Experimental Work. ANON. Surveyor (Br.) **94**: 329 (Sep. 16, '38). Av. water consumption approx. 19 m.g.d. (Imp.) and cost of filtration and chlorination, excluding capital charges, was 1.25¢ (Straits) per 1,000 gal. (Imp.) Experimental work now under way on use of surface wash. Liming after sedimentation discontinued because it was found that the increase of pH resulted in solution of alumina floc. An experimental plant consisting of a rotary screen strainer and rapid sand filter was put into action in expectation that the rotary screen would remove portions of the floc remaining in the water leaving the sedimentation basin. The floc appeared to break up, to pass the screen, and to reform afterward. Screen used had 100 meshes per inch. Proposed to experiment with finer mesh. The experiment with the 4'' rubber pipe in the sea is being continued, as described in '36 Annual Report. After submersion of more than a year the pipe withstood 100 lb. per sq. in. for 20 min.—*H. E. Babbitt.*

Typhoid Deaths Dropped as Water Improved. ANON. Pittsburgh's Health **6**: 1: 13 (Jan. '38). In 1802, population of Borough of Pittsburgh was 1,600 persons. At that time water supply was a number of wells and pumps erected in different parts of town. In 1824, the Council passed an ordinance providing for a loan of $50,000 and an additional sum of $40,000 in 1826 to build a general water works. A pump station and reservoir were constructed. In 1838, a new reservoir site was purchased and in July 1844 a new pump station was put in operation. In 1848, $30,000 for construction of a new reservoir was appropriated. In 1847, Lanning of Cincinnati urged the Council to install a filtration system. This is the first American city on record to be urged to install filtration. One million dollars was authorized in 1868 for extensions and improvements. From that time to 1907 when filtration was installed, a few small improvements were made and reports of water problems investigated. An experimental filter set up in 1895 with a diameter 6¾′ x 6½′ high proved the water could be purified satisfactorily. Since '32, five pumping stations were completed. In '36, total investment in fixed capital was

$36,425,860. The typhoid death rate dropped from 110. per 100,000 in '06 to 0.7 per 100,000 in '36.—*P. H. E. A.*

Denver, Colo., Board of Water Commissioners, 1937 Annual Report. GEO. F. HUGHES, Ex. Sec'y and D. D. GROSS, Chief Eng. of Denver Water Dept. operating organization. Private company supplying territory purchased in '18 by city, present worth $42,000,000. 350,000 pop. in Denver and adjoining territory served. Impounded supply mostly derived from melting snows. South Platte River main supply, has watershed of 3910 sq. mi.; entirely independent supply recently completed in mts. west of Continental Divide on Fraser River and tributaries. Moffat Water Tunnel part of this project. Storage res. and cap. in mil. gal. are: Antero (City owns 60% of water)—10,843; Eleven Mile Canon—26,693; Cheesman—25,763; Soda Lakes (30% of water owned)—653; total storage—63,952 mil. gal. In addition 3 operating res.—Platte Canon, Marston Lake and Ralston contain 10,044 mil. gal. 5 filter and 1 infiltration plant operated—Kassler, slow sand, cap. 30 m.g.d.; Willard, Marston Lake South side, Marston Lake North side, and Moffat all rapid mechanical with cap. in m.g.d. respectively of—15, 21, 64, and 56. All water filtered. City pipe system has 758 mi. of mains, 4508 fire hydrants, and 72,558 service connections, 2% of services metered. 175 gal. per capita daily used, av. consumption during winter 44 mil. gal.; av. summer day—89 mil. gal., one peak summer day—123 mil. gal. used. Total revenue—$2,695,712; $2,020,966 from water revenue. Total operating expense—$765,340, interest expense—$845,041; net income—$610,123. Av. hardness Denver water—109 p.p.m. (as $CaCO_3$); av. pH—7.67; av. chlorides—18.96; av. fluoride—0.8; temp. av. 14.8°C. max. —22°, min. —10°. 92.8% to 98.9% bacteria removed in purification.—*Martin E. Flentje.*

New Bedford, Mass., 1937 Report of the Water Board. Officers include L. E. J. CARNEY, Mayor and Board Pres. and STEPHEN H. TAYLOR, Clerk and Supt. City owned supply is pumped from Great and Little Quitticas Ponds, 11 mi. N. of city through 48″ steel main 8¼ mi. long. Pop. supplied—121,525; total consumption for yr. 3606 mil. gal. of which 84½% was registered by meters; av. daily consumption 9.58 mil. gal. equiv. to 81 gal. per day per consumer and 458 gal. per day per tap. Av. rate rec'd per mil. gal. metered equalled $107.03; rec'd per mil. gal. pumped was $90.70; cost of supplying based on total maintenance and per mil. gallons consumed—$50.58; on total maintenance plus interest on bonds—$65.02; total—$92.74. Total income rec'd from consumers—$355,330; operation and maintenance costs were $189,256; total costs maintenance and interest—$240,824; total construction expenditures—$79,966. C.i. and steel mains used, 4″ to 48″; 213.5 mi. now in use, 521′ added during yr.; cost of maintenance per mi.—$17.56. No. of leaks per mi.—0.084. 2 new hydrants added, total now 1905 (public) and 420 private. System has 2930 stop gates in use, 207 blow offs. Pressure ranges from 16 to 91 lbs. 144 mi. of services from ½″ to 10″ size in use, extended 1659′ during yr. and discontinued 364′; 62 taps added, total now in use 17,647; av. cost of installing service $103. 3555 mil. gal. pumped by steam with 846 gal. pumped per lb. of coal; av. static head 167.74′, dynamic head 178.31′. 16.8 mil. gal.

electric pumpage, with 1010 gal. per kw. hr., av. cost per kw. hr. $0.022. Total cost (figured on pump station expenses) pumping per mil. gal.—$13.43, per mil. gal. raised 1′ (dynamic)—8¢. Water temp. in system ranged from 38° to 78°F. Rainfall for yr. 45.83″; greater than past 43 yr. av. Pond water color varies from 22 to 65, 10 p.p.m. hardness, alk.—5 to 8 p.p.m., chlorides—5 p.p.m., Fe 0.06—0.30 p.p.m., Mn—0.02 p.p.m.—*Martin E. Flentje.*

Hartford, Conn., 1937 Report of Water Bureau. CHAS. A. GOODWIN, Chair. of Board, CALEB MILLS SAVILLE, Mgr. and Chief Eng. Water supplied to Hartford, Bloomfield, Newington, Windsor and Wethersfield with est'd. pop. of 345,000. Av. daily consumption highest on record, 19.347 m.g.d. as compared with 18.945 m.g.d. in '36. Total income—$1,120,366; cost of operation—$326,520; interest on bonds—$130,985; total expenses—$458,513. Following portions of revenue dollar used for expense: collecting system, 5.8¢; purification, 2.5¢; distribution, 7.5¢; general repairs, 0.5¢; general and misc., 12.1¢; fixed charges, 38.5¢. Supply from impounding reservoirs by gravity, res. cap. 8,562 mil. gal., publicly owned by Metropolitan District. Total water consumption for yr.—7061 mil. gal., equal to 79 gal. per day per consumer. Cost of supplying water on total maintenance—$77.70 per mil. gal.; total cost maintenance plus fixed charges—$138.74 per mil. gal. Pipe—1″ to 48″; 32,507′ added in yr. and 4253′ discontinued; total in use—427 mi. 35 hydrants added; total now 3232. 10,134 gates in system; 181 added in '37. Pressure range 15 to 115 lbs. 635 service taps added; total in use—28,596. 698 meters added; total—27,796. Hydrographic data included: rainfall, (1) Nepaug watershed was 61.18″, 25 yr. av.—44.76″; (2) East Branch—52.56″, av.—44,28″; (3) West Hartford—53.29″, av.—43.55″. Total water filtered was 7047 mil. gal., equiv. to av. filtering rate of 3.75 mil. gal. per acre per day. Cost of filtering was $3.96 per mil. gal., has ranged from $2.51 to $4.60 in period '23–'37. Raw water 20°C. count av'd. for yr. 265, filtered water—78; filtered 37° count av. was 40; av. hardness—11 p.p.m., color, raw—25, filtered—15; pH—6.5. Discussion of lowering water rates and comparison with various comparable cities given; exptl. work under way on filtration; during yr. extensive tests made with Meter Master rate recorder to determine actual rate at which water used in bldg's. In approx. ½ of cases possible to reduce meter size. Based on 39 meters, net increase in registration through smaller meters during first 6 mo. service was equiv. to revenue increase of $25.–$60. per yr. per meter.—*Martin E. Flentje.*

Wanaque Water Supply System. Report of Operation, 1937. North Jersey Dist. W. S. Comm. CHRYSTAL BROWN, Supt., P. R. FRANKLIN, Chairman. Operating data and review of historical material in former reports. Work on supply begun soon after Oct. '18 when first contract signed with Newark, N. J. for supply of 50 m.g.d.; plan enlarged in '24 to 100 m.g.d. and finally in May '24 to aqueduct cap. of 150 m.g.d. Communities with water allotment in m.g.d. as follows: Newark 40.5, Paterson 20, Kearny 12, Passaic 11, Clifton 6.75, Montclair 5, Bloomfield 4, and Glen Ridge 0.75. Supply consists of res. with surface, when full, at elev. 300.3, 200′ above business center of Newark, Paterson and Passaic. Res. has 2300 acres water surface with total cap. of 29

billion gal. Av. depth 37′, max. 90′; formed by 8 dams impounding waters of Wanaque River, Ringwood, Cupsaw, Erskine, Blue Mine and West Brooks and partial diversion of Post Brook. Res. within 5700 acres Commission owned lands, watershed area 94.4 sq. mi. Total length of aqueduct over 21 mi., with crossings of Wanaque, Pequannock and Pompton Rivers. System put in operation Mar. 20, '30. City of Bayonne now supplied with surplus water. Watershed protected by frequent surveys and restrictions, contains approx. 2525 bldgs. with permanent pop. of 2650 and summer pop. of 8650. Res. shore patrolled. Weighted av. rainfall for '37 was 55.22″, av. for period '21 to '37 inc. 47.27″, min. '37 mo. rainfall 2.79″ in Mar. and max. 7.69″ in Aug. Crest of overflow weir with flashboards 301.57, max. elev. of res. was 302.08 on May 15 and min. 288.10 on Jan. 1. Total flow of streams during year 43,227 mil. gal. Av. daily consumption of water was 71.29 mil. gal., max. 88.7 mil. gal. on Jun. 2. Color of water (true color) varied between 7 and 10 at surface level, between 9 and 12 at intermediate and 9 and 35 at bottom; CO_2 varied from 1.8 to 5.6 p.p.m. at intermediate level and 2.2 and 10.8 p.p.m. at bottom. Two peaks in microscopic organisms encountered, one in May and other during Aug. Total 37°C. count on delivered water av. 3 per cc., with none of samples showing positive coli-aerogenes test. Max. chlorine treatment 1.1 p.p.m. Stream chlorination ahead of res. caused 81.7% reduction of coli-aerogenes forms. Lime treatment for corrosion protection automatically controlled, max. treatment 80.07 lbs. per mil. gal., min. 28.61 and av. 49.41 lbs. Run-off of watershed 29.40″, equal to 1.32 m.g.d. per sq. mi. and ratio of 0.53 run-off to rainfall. Total operating expenses $272,036, cost of $10.45 per mil. gal., a reduction from the av. of $11.85, for total cost from beginning of operation. Av. cost of chlorine $0.25 per mil. gal., lime $0.224, copper sulfate $0.039, all water treatment $0.697. Av. mo. chem. analysis showed water delivered had temp. of 9°C., cold and hot odor of 2, turb. 2 p.p.m., color 10 and 13 (apparent), 3.3 p.p.m. chlorides, 19 alkalinity, total hardness of 19, pH of 8.65, Fe 0.07, Mn 0.13.—*Martin E. Flentje.*

Compilation of Principal Operation and Cost Data for Water Purification Plant at Lima (Ohio). E. E. SMITH. Ann. Rept. Ohio Conf. Water Purif. **17:** 66 ('37). Lima water supply, derived from Ottawa R., after long storage in shallow impounding reservoirs, is coagulated with alum, filtered through rapid sand units and sterilized with chlorine. Complete operating, analytical and cost data available for 18 yrs. More important are tabulated in duplicate on commercial worksheets, "National Analysis Pad No. 5321, Eye-ease Paper," providing 21 columns. When framed, overall size is 27″ x 25″. One copy kept in superintendent's office and other in purification plant lobby for ready reference by operators and visitors. Tabulations are included (in the paper) showing chemical characteristics of water and temp. data.—*R. E. Thompson.*

Water Plant Operation at Kansas City, Mo. ANON. Eng. News-Rec. **121:** 300 (Sep. 8, '38). Brief data given from annual report ('37) of T. D. Samuel. Theoretical detention period in North Side purification plant is 17 hrs., divided as follows: pre-sedimentation 4 hrs.; mixing ½ hr.; primary coagulation 9 hrs.; final coagulation 3½ hrs. Av. dosages of chemicals in lbs. per mil. gal. were as

follows: alum 329, lime 183, ammonium sulfate 6.2, chlorine 7.4. All alum used, some 3,000 tons, was manufactured by dept. at cost of $13.78 per ton for materials, power and labor, or $15.25 per ton delivered to storage bin, including maintenance parts and labor, interest and depreciation. Total cost of purification was $8.86 per mil. gal., of which $3.56 was cost of chemicals for sedimentation and sterilization.—*R. E. Thompson.*

What the Annual Municipal Report Should Contain. CLARENCE E. RIDLEY. Public Management. **20:** 328 (Nov. '38). Based on address before League of Wisconsin Municipalities; summary of "Specifications for the Annual Municipal Report," just published by International City Managers' Assoc., Chicago (50¢). Deals with report covering all city departments. Report should be designed to interest and inform citizens. Should be brief, attractive, issued promptly and easily understood. Recent model report about 50 pp., profusely illustrated with "pictures, charts and graphs." Under public works should state amount and quality of water supplied, improvements made and cost of water per mil. gals.—*M. N. Baker.*

HYDROLOGY

Snow Surveys. R. C. FARROW. Eng. J. (Eng. Inst. Canada) **21:** 451 (Oct. '38). In mountainous and forested regions, snow is largest contributor to stream run-off. Has been shown 200 typical streams in British Columbia av. 85% of their run-off in 7 mo. from Mar. to Sep. due largely to melting snow. Snow itself variable, elastic and varies greatly in density, in newly fallen condition density may vary from 5% to 18%, in single season on British Columbia courses, density varied from 19.4% to 71.1%. Snow surveying relates snow cover to streamflow. Expts. since '04 in Nevada have shown (1) that over given basin relative snow cover is the same, if water content found to be 75% of normal at some point, other points will have same moisture content within small error regardless of snow depth; (2) that percentage of normal of water content of snow pack at end of snow-fall season agrees closely with percentage of normal streamflow to be expected in ensuing run-off mo's. In some locations correction must be made for soil-priming factor, in Canadian work a correction curve based on pptn. worked out for certain areas that works satisfactorily. 2%-5% accuracy in forecasts of run-offs becoming common. Higher altitudes of mts. well above timber line yield very little water to run-off, most is dissipated through evaporation. Forests great conservers of snow, an unforested talus slope with total season's depth of snow 40.8" had water content of 18.4", forested slope had 88.6" snow with 41.1" water. Snow course is a permanently established line over which measurements of depth and water content are made at fixed observation pts. 100' apart. Sampling done with jointed aluminum alloy tubes, slightly over 1½" diam., graduated in inches for measuring depth. Cutter at bottom, has throat diam. so that 1 oz. of weight is equiv. to 1" water-content. Weighed on spring balance. On 10 streams in British Columbia, error in forecasts of run-off in per cent of actual varied from 0.05% to 25.2% in '37 (only 1 of magnitude 25.2%, remainder from 0.5% to 7.0%). Total of 30 courses used for forecasts.—*Martin E. Flentje.*

Rainfall and Evaporation since Jan. 1935 and the Ground Supply. E. VAN EVERDINGEN. Water (Netherlands) **22:** 126 (Jul. 1, '38). Precipitation during the last three years has been normal, respectively 88, 69 and 52 mm. The surplus of water in the ground has increased, but there are considerable variations in different parts of the country,—from 132 to 348 (mm. ?). Local conditions are more important than general. Decrease in surplus occurs during the summer, while maximum is reached in March–May. Evaporation is greater than rainfall in summer. The "normal surplus" is tabulated for a number of places, while conditions for one place are graphically illustrated. Previous studies showed a decrease in ground water level amounting to 900–1000 mm., with an evaporation of 290 mm.; the recent studies show an increase of 660 to 800 mm. in ground water level with a surplus of 339 mm. The ground water levels are directly dependent upon the surplus of rain over evaporation in relation to normal conditions. If rainfall cycles of 27 mos., $5\frac{1}{4}$, 7 and 9 yrs. are taken in connection with sun spot cycles the period Dec. '37–Nov. '38 should produce a shortage of 30 mm., for '39 a surplus of 80 mm.—*Willem Rudolfs.*

Evaporation (Area) and the Hydrological Cycle. DAVID LLOYD. Wtr. and Wtr. Eng. (Br.) **40:** 297 (Jun. '38). The phenomenon examined is called total loss,—that is the difference between the general rainfall over a drainage area and the observed total run-off. This can be formulated as

$$X_1 = f_2(X_2) + f_3(x_3) + f_4(x_4) + h(G)$$

in which X_1 is loss; X_2 = rainfall; x_3 = temperature; x_4 = sunshine; and G the geological factor. The five dimensions prevent diagrammatic representation so that the part relation is shown in the three dimensional continuum illustrated. A dimetric plane is drawn in three dimensional projection, there being a slight warping of this plane surface. The analysis is commenced by obtaining the multiple linear equation by the method of least squares and proceeding by Ezekiel's successive approximations to the curvilinear regressions. Data observed at 8 stations were available.—*H. E. Babbitt.*

Rate of Evaporation from a Free Water Surface by a Perpendicular Air Stream. M. C. MOLSTAD, P. FAREVAAG AND J. A. FARRELL. Ind. Eng. Chem., **30:** 1131 (Oct. '38). Circular water surfaces of 0.05 to 0.37 sq.ft. area (watch glasses 3'' to 8.25'' diam.) were subjected to a perpendicular air stream with velocities of 3′ to 15′ per sec., corresponding to mass velocities, G, of approx. 800–4000 lbs./sq.ft./hr. Tests at prevailing room temp. and humidity and at the lower velocities gave evap. coeffs. (k' = lbs. of water evaporated/sq.ft./hr./unit humidity difference) about 50% greater than the accepted coeffs. for evap. of water to an air stream flowing parallel to the surface. At higher velocities, results were about 10% above those obtd. by Lurie and Michailoff for parallel flow, but 30% below those of Shepherd, Hadlock and Brewer. No explanation of this anomalous situation is offered. Coeffs. were found to fall on a line having the equation, $k' = 1.42\ G^{0.37}$. Heat transfer coeff. is $h_c = 0.37\ G^{0.37}$. Coeffs. in still air were only about 2% of those at the lowest air vel.

Tests also made with air streams at 125, 175 and 225°F. and with moistened Celotex insulating board instead of free water surface. Authors believe that at the lower mass velocities, a perpendicular air stream causes greater turbulence and therefore gives higher coeffs. of mass transfer than does a parallel air stream, while at the higher velocities the turbulence in both cases is sufficiently great so that the difference in coeffs. becomes small and may disappear.—*Selma Gottlieb.*

Evaporation of Water into Quiet Air. B. F. SHARPLEY AND L. M. K. BOELTER. Ind. Eng. Chem. **30:** 1125 (Oct. '38). Evaporation from a 1′ diam. circular pan of distilled water into quiet air at 53% humidity was measured for water temps. between 63° and 93°F. Surface of water was at level of surroundings. In the critical region, corresponding to 69.4°F. water temp., buoyant effects of the air-water vapor mixture at the water surface and far away are equal. Above critical region, unit evap. rate in lbs. per sq. ft. per hr. is $e = -0.024 + 65\ (c_{vw} - c_{v\infty})$, where c_{vw} is concn. of water vapor on the gas side of the gas-liquid interface and $c_{v\infty}$ is concn. of water vapor in the atmosphere far away from the pan, both in lbs. per cu. ft. Below the critical region, $e = 18.75\ (c_{vw} - c_{v\infty})$. Tentative correlation of thermal free convection and diffusional free convection data also reported.—*Selma Gottlieb.*

Reviewing the Official Report on the Record Los Angeles Flood of Mar. 2, ('38). ANON. W. Cons. News **13:** 328 (Sep. '38). This flood in Los Angeles Co. exceeded any flood of record, caused loss 113 lives and $45,000,000 damage. From meterological point of view worse conditions are possible and could be expected to produce more intense and longer storm; the max. day's rainfall exceeded previous max. by about 20% and had probable recurrence frequency of 65 yrs. Calculation of probable frequency in yrs. of various storm duration periods of from 5 min. to 24 hrs. indicated Mar. 2 storm was characterized by exceptionally infrequent intensities for the time periods of 5 hr. or more (5 hr.—1.52″ per hr. intensity, probable frequency, over 100 yrs.; 24 hr.—15.96″, or 0.66″ per hr., probable frequency over 100 yrs.), with shorter periods giving much more probable frequencies—3 to 25 yrs. for 5 min. to 2 hr. periods. Loss in storage cap. of res's. from debris varied from 3% to 80% and av'd. 12½%. Rates of erosion varied from 12,000 to 80,000 cu. yd. per sq. mi.—*Martin E. Flentje.*

Ohio Water Works in the 1937 Flood. Cincinnati. A. S. HIBBS. Ann. Rept. Ohio Conf. Water Purif. **17:** 70 ('37). In Cincinnati, 52′ is flood stage. Flood of Jan.–Feb., '37, reached record stage of 80′, 9′ higher than flood of 1884 and 10.1′ higher than flood of '13. Jan. rainfall was 13.48″, approx. 4 times normal of 3.48″. Main pumping station shut down due to flooding on Jan. 24, at which time there was about 140 mil. gal. in storage. About 5 mil. gal. was released each day into system and industrial plants and neighboring towns pumped about 8 m.g.d. into mains through temporary connections. Normal consumption is about 60 m.g.d. Tanks of all descriptions were filled with water and placed in schools, refugee stations, etc. Notices published in

papers, radio announcements and signs at all tanks and water stations warned that all water should be boiled 10 min. before drinking. First pump in main station was placed in operation again on Feb. 2 and following day all necessary pumps were operating. Samples from hundreds of points in dist. system showed heavy contamination in some localities, probably due to back-siphoning from toilet fixtures. Chlorine applied to maintain residual of 3 p.p.m. and "boiling order" was not rescinded until chlorine reached outer limits of system. Not a single case of typhoid or other intestinal trouble due to flood. Steps being considered to render system immune to such floods. Fire which involved property loss of $1,500,000 resulted from gasoline storage tanks being forced from foundations by rising waters.—*R. E. Thompson.*

Water and Wind on the Shore. H. W. RICHARDSON. Eng. News-Rec. **121:** 424 (Oct. 6, '38). Devastation in shore communities by hurricane of Sep. 21 is described. In New London, Conn., rainfall was 0.97″ on 19th, 2.83″ on 20th and 6.5″ on 21st. Failure of power supply, combined with flooding, interrupted operation of pumping station that serves ⅓ of city, including high-pressure fire lines; remainder of city served by gravity. During storm, conflagration occurred which quickly enveloped 3 city blocks. Despite huge waste from broken hydrants, mains, etc., and drain of 9 fire pumping engines, supply did not fail, but pressure dropped to 5 lb. High-pressure mains supplied by fire engine connected to low-pressure hydrant. Within 48 hrs., water was being supplied to all parts of city with aid of emergency pumping equipment. Power restored at pumping plant on Sep. 25. In Providence, R. I., wall of water, superimposed on high tide, inundated area of 1¼ sq. mi. in heart of business section, in some places to depth of 12′. Water works functioned normally during crisis.—*R. E. Thompson.*

SERVICES AND METERS

The Avoidance of Frost Bursting in Water Pipes. J. MCKEOWN. Wtr. and Wtr. Eng. (Br.) **40:** 600 (Dec. '38); Contract Jour. (Br.) **119:** 1794 (Nov. 30, '38). Research made on effect of frost on water pipe to detn. effect of properties of materials, effect of low temps. on these properties, process of ice formation and its mechanical effects in pipes. Freezing of water accompanied by 9% expansion in volume which may be accommodated by water moving along pipe back into another pipe, into main for example; by expansion of pipe; or by escape of water through pipe failure. Unrestricted movement of water along pipe averts many freezing failures. Tests between +20°C. and −20°C. on various pipe materials show that variations in properties of hard and soft copper, lead and various lead alloys, while appreciable, do not offer practical means of avoidance of trouble from frost bursting, except in one respect: The harder the pipe material the greater the length of ice plug which can be moved to avert failure; but plugs may only be moved when formed in perfectly straight, smooth, uniform pipe. In the experiments, wrapping of pipe in exposed places lowered freezing chances by 50%, boxing-in almost wholly prevented freezing. Closing stop-cocks preventing free movement of water

into main or storage tank greatly increases risk of frost bursting. In England 2′ cover over service pipes generally sufficient for frost protection.—*Martin E. Flentje.*

Concerning Service Pipe for Water Supplies with Special Reference to Copper. ANON. Health News, N. H. State Board of Health **16:** 5: 6 (May '38). Discussion of relative merits of different materials for water service pipe when used with soft eastern waters. Suggests use of cement-lined iron pipe or special alloys that resist corrosion. Article intimates death of goldfish may often be caused by presence of copper compounds derived from corroding service lines. Attention called to public health hazard from continued human consumption of water carrying substantial copper content.—*P. H. E. A.*

Selection and Use of Copper Alloys in Water Works and Sewerage Practices. N. W. MITCHELL. W. W. and Sew. **85:** 555 (May '38). An article discussing comparative corrosion resistance values of copper alloys. Corrosiveness of a water depends upon its dissolved salt content and extent to which oxygen and CO_2 are present. High free CO_2 content causes staining of plumbing fixtures. The sulfate content is important and when it is above 50 p.p.m., water is likely to be corrosive. Chlorides, also, are factors in corrosiveness. Silica, alone, has little bearing on corrosiveness. This is true also of iron and aluminum unless they are present in large quantities. Brass is an alloy composed of copper and zinc. Muntz metal is 60–40 brass (meaning 60% copper and 40% zinc) and is composed of two sets of crystals. It corrodes by a selective attack of the beta crystals. High brass pipe is an alloy containing about 67% copper, 0.5% lead and 32.5% zinc. Its microstructure consists of a single constituent; namely, the alpha phase. This alloy is subject to a form of corrosion known as "dezincification" which is the removal of the zinc. Red brass pipe, an alloy containing 85% copper and 15% zinc, is not subject to "dezincification" in plumbing work. Ductile copper tubing has been used extensively. Soldered fittings satisfactorily resist corrosion under normal water conditions. In 23 cities scattered over the country, 29 test installations of copper alloy were made on both hot and cold water lines. At end of 5 yrs. of tests, the red brass and copper had suffered no appreciable corrosion in any of the installations. The other brass alloys suffered dezincification in both hot and cold water lines in those cities where the water is corrosive, due to high salinity. Recommended pipe materials: Red brass recommended first, copper tubing, second, for waters which are corrosive due to high salinity. For those water supplies exceptionally high in free CO_2 content and low in temporary hardness, tin coated copper water tubing is recommended as first choice. Copper alloys in sewerage: Sewage is likely to be more corrosive than most domestic water supplies. Behavior of some of the high copper alloys in sewage indicates that the sewage proper is not destructive to the bronzes or to red brass, usually. Silicon bronze has a high corrosion resistance. Olympic bronze has been used successfully in sewage treatment plants. Copper tubing has been used satisfactorily as heating coils in sludge digesters.—*P. H. E. A.*

Lead Poisoning Due to Tinning Should Be Kept in Mind. M. CARRIEU, R. CABANNES, J. FOURCADE AND A. BLAVOUX. Rev. d'Hyg. et de Med. Preventive **60:** 454 ('38). Tin, being malleable and not easily attacked by air, is an extremely useful metal for coating other metallic surfaces. In France, the law has been clear for many years that no tin used for coating articles employed for holding food may contain more than minute traces of lead, if any at all. Notwithstanding this prohibition, tin is being used containing high percentages of lead, and cases of lead poisoning are resulting.—*W. P. R.*

New Materials in Gas and Water Technique. BARTELS. Z. öff. Wirtsch. **4:** 375 ('37); Wass. u. Abwass. **35:** 363 ('37). Discusses materials which are being introduced in Germany to take the place of imported metals in gas and water works. In pipes, lead, tin-lined lead and copper are being little used. Various types of steel ("Remanit," a chromium-manganese steel, and "Hagusta," steel with a coating of hard rubber), aluminium and aluminium alloys are being used. Non-metallic materials include porcelain, glass, stone-ware; hard wood, and rubber.—*W. P. R.*

Analysis Chart for Meter Tests. EDWARD NUEBLING. W. W. Eng. **91:** 1472 (Nov. 9, '38). Yrs. of experience in analysis of water meter data led to construction of chart to show accuracy and loss of head of meters under various flow conditions. Vertical lines are graduations of rate-of-flow scale "Flow Through Meter in Cu. Ft. per Min." and are spaced in accordance with the sq. roots of numbers. Horizontal lines are graduations of loss of head scale, are spaced in accordance with the fourth roots of numbers. This one form of chart suitable for all sizes of meters, gives straight line loss of head graph and an accuracy curve that covers entire range of meter bringing out clearly the important accuracy at the lower rates of flow.—*Martin E. Flentje.*

PUMPING EQUIPMENT

Maintenance of Electrical Equipment in Water and Sewage Plants. S. A. CANARIIS. W. W. and Sew. **85:** 287 (Apr. '38). Satisfactory operation of electrical equipment depends on good maintenance. This should be systematized by means of forms and scheduled testing. In general, minimum insulation resistance should be 1000 times working voltage, expressed in ohms. Except for specially designed equipment, max. total temperature should not exceed 90°C. Bearing temperature rise should not exceed 45°C. for friction type bearings, 15°C. for anti-friction type bearings. Dryness and cleanliness of insulation are essential, hence regular cleaning with cloths or compressed air or both and re-varnishing (baked), should be a regular practice. For oil and grease removal, a solvent may be necessary. Permanent drying oven is worthwhile investment. Coil bands must be inspected for looseness, commutators kept true and tight, and commutator front "V" ring clean and dry. Brushes should maintain good contact and free movement. Circuit breaker oil should be inspected annually or after 200 normal operations, replaced when flashover value drops below 18 kv. On such equipment, cleanliness and proper

adjustment are vital. Don't put coil or armature on floor. Don't rest armature on its coils. Don't lift armature except by shaft or with wide lifting belt. Don't use spray without grounding nozzle. Don't use solvents without adequate ventilating and fire extinguishing facilities. Don't overlook manufacturer's instructions or services.—*H. E. Hudson, Jr.*

Impellers Used in Centrifugal Pumps. T. S. WALL. Contract Jour. (Br.) **119:** 1518 (Nov. 9, '38). The author recounts experiences in determining experimentally the best type of impeller for centrifugal pumps handling water containing 30% fine grit. The pumps were rated at 500 g.p.m., 115′ head, 1450 r.p.m. A double suction shrouded impeller failed after 10 days operation. Open type impellers were tried and the life of the impellers was increased to five weeks, then to eleven weeks. No statements are made about relative efficiencies. [From the sketches of the impellers, efficiencies must have been greatly reduced to obtain the longer impeller life.] A single suction type pump was installed. A double shrouded impeller gave six weeks use, but efficiency was greatly reduced by the grit getting into the close side clearances between the shrouds and the casing. A booster pump, using 10% of the rated power of the main unit was attached, discharging clean water into the space between the case and the impeller shroud. The operating cost of this scheme was prohibitive. Difficulty was solved by installing a small impeller on the shaft back of the main impeller to discharge clean water into the space between the casing and shroud. Author discusses the difficulties arising from stuffing box troubles, especially for pumps handling gritty water. He describes the development of a small impeller to furnish a water seal ahead of the stuffing box. [The operating troubles which this author discussed and which he has solved have been guarded against by the designers of pumping equipment in the U. S. for many years. Standard pumps, designed for sewage or any fluid carrying gritty material are available, practically "off the shelf."]—*Homer Rupard.*

Economics of Pumping Equipment. D. D. EAMES. J. N. E. W. W. A. **52:** 214 (Jun. '38). Comparison made of pumping by 3 types of power: (1) electric power from central power plant, (2) Diesel engine, (3) steam engine or turbine. Costs compared in 4 stations, (1) av. load less than 250 hp., (2) av. load 250 to 500 hp., (3) av. load of 500 to 1000 hp., (4) av. load more than 1000 hp. In all cases total pumping head 250′, cost of coal $6.00 per short ton, fuel oil 7¢ per gal., lubricating oil 50¢ per gal. and electricity 1½¢ per kw. hr. Detailed summaries of investments and annual costs tabulated, author summarizes that for entirely new plants of larger size Diesel-driven pumps most economical, but with steam-driven units sufficiently close to justify most thorough consideration. Electric units for smaller capacities excel steam units and approach Diesel units; for smaller sizes electric units would surpass both Diesel and steam units. For equipment in existing stations, the Diesel units retain their lead, with steam units pressing them more closely and surpassing them for largest size. Emphasized, however, that for any particular installation none can be ruled out arbitrarily and analysis req'd in each case.—*Martin E. Flentje.*

Diesel Pumping Plant at Milford, Mass. M. H. GOFF. J. N. E. W. W. A. **52**: 225 (Jun. '38). Reduction of pumping costs both for fuel and labor, increasing attractiveness of station, systematization of pumping service, quicker pick-up in emergencies and increased efficiency are benefits of change to Diesel power. Plant has 3 Diesels: 1-100 hp. direct-injection engine, 1-125 hp., 5 cylinder, 4 cycle, 1-6 cyl. 180 hp., 4 cycle engine. Centrifuge used for cleaning lubricating oil. Use has av'd. 1 gal. to every 4000 hp.-hr., in '37, 31,991 gal. of fuel oil used in pumping 312 mil. gal. supplying 3380 services with av. of 0.850 m.g.d., max. of 1.40 m.g.d.—*Martin E. Flentje.*

Hand Injuries Due to Injection of Oil at High Pressures. D. E. DIAL. J. Amer. M. Ass. **110**: 1747 (May 21, '38). Fuel for Diesel engines is forced through fine jets into the combustion chamber at pressures as high as 6,000 lb. per sq. in., in order to produce finely divided particles for rapid combustion. Should this fine jet of oil under high pressure come against the skin, say of the finger or hand, severe injury results. Two cases are reported. In one the tip of the index finger was concerned; the entire distal phalanx became necrotic and had to be amputated, while the *Flexor profundus* tendon sloughed; small pieces of wax kept being extruded from the stump for weeks after the amputation. In the other the volar surface of the left index finger was affected; free incisions were resorted to; eleven days later the subcutaneous tissue was grey and necrotic; finally the finger was saved but without movement in the distal interphalangeal joint. Experiments on a rabbit's ear produced sterile abscesses.—*B. H.*

CONCRETE

Subzero Concrete Pumping. F. A. DALE. Eng. News-Rec. 121: 407 (Sep. 29, '38). Experiences with pump-placement of concrete at Solon Dam on Kennebec R. (Central Maine Power Co.), with temps. as low as −20°F., are described. Insulation of pipeline is unnecessary. Concrete with slump as low as 1½" pumped without difficulty. No segregation or plugging occurred: care, however, was taken to provide sufficient friction to counteract following steep drops. Pumping can be interrupted for at least 20 min. without plugging. Transportation from pipe outlet to final destination in forms accomplished by chutes, angle being adjusted to just keep concrete moving. All concrete was puddled with internal vibrators: unformed surfaces were consolidated with surface vibrator. Pipeline was cleaned after each pour by forcing go-devil through it with air or water. Cost of handling aggregate and concrete was $1.70 per cu. yd. and cost of heating aggregates and concrete, before and after placing, $0.39 per cu. yd.—*R. E. Thompson.*

Experiments on the Freezing of Building Materials. W. N. THOMAS. Dept. Scient. & Indust. Res. Building Res. Technical Paper No. 17 ('38). London: H. M. S. O. For many years it was generally considered that frost was the most powerful agent in the disintegration of building materials, such as natural stone, bricks, and tiles. Recent work has shown, however, that in many cases

damage attributed to frost action is, in fact, caused by other agencies, such as the crystallisation of salts in the pores of the materials. Furthermore, disruption apparently due to frost action may be the cumulative effect of a sequence of causes, of which freezing is but the last. For example, the freezing of water in cracks or fissures caused by some other form of attack may bring about the complete disintegration of a material which, if uninjured, would have withstood frost action of considerable severity. Experiments are described. Slow rates of freezing of saturated material are accompanied by appreciable extrusion from the surface, and by only small extensional strains. Rapid rates of freezing, on the other hand, are usually accompanied by large extensional strains, which are liable to cause more damage. Materials which are not fully saturated receive additional relief owing to possibility of intrusion into previously unfilled pores. Generally, if saturation is below 80%, little, if any, damage occurs, but effect varies with different materials, and with rate of freezing. After all contained water has frozen, further fall in temperature does not appear to cause further damage, strains actually being diminished. Since extrusion is important factor in providing relief, any conditions which tend to limit or prevent extrusion will be detrimental to the frost-resistance of the material. Thus, choking of pores near or at the surface, either by deposition of salts due to natural weathering actions, or due to application of preservatives such as waxes, paints, etc., may increase liability to damage through frost action, if material can become saturated through ingress of water at other faces.—*W. P. R.*

Repair and Maintenance of Concrete. R. B. Young. Can. Engr. **75:** 14: 6 (Oct. 4, '38); **75:** 18: 6 (Nov. 1, '38). Extensive, practical discussion, based largely on experience of Hydro-Electric Power Comm. of Ontario. Subject dealt with under following headings: surface treatments, waterproofing, pointing and caulking, patching, surfacing with mortar, and replacement. As a class, paints have very limited use in preventing deterioration of concrete; moreover, best of paints have relatively short life. Theory on which claims for transparent waterproofings are based is sound but, as a class, they are very disappointing; few are effective for more than few months. Varnish type of waterproofing is poorest of all. Iron treatments consist of applying very finely divided iron particles and sal ammoniac to wet surface in form of grout. Their efficiency as a surface waterproofing is doubtful. Bituminous waterproofings, where used as paints, have latter's shortcomings. Wherever practicable, movement of water should be cut off at source, e.g., on side of retaining wall next to ground, upstream face of dam and internal surface of pipe or conduit. Bituminous waterproofings most effective when applied in this manner and have the property of maintaining their effectiveness in contact with water. Emulsified asphalts give better results than cut-back asphalts. Surface should be thoroughly cleaned, primed with asphalt which has been well thinned to give max. penetration and then covered with 2 or more coats of asphalt; or better, putty of asphalt and sand or cement may be applied with trowel to desired thickness, usually $\frac{1}{16} - \frac{1}{8}''$. Admixtures of cement or sand increase the mech. strength. Cement plaster is the only treatment available for waterproofing surfaces to be painted decoratively. Most satisfactory treatment to prevent moisture passing through cracks in walls is grooving, caulking and

pointing, if cracks are structural and few in no.; for more numerous shrinkage cracks, coating of cement paint or treatment with raw linseed oil is best. Latter can only be employed on walls normally dry and not in contact with ground or other continuous source of moisture. Preventing passage of water through construction joints and structural cracks, especially if under pressure, is difficult problem. If not subject to freezing temps., caulking may be employed. Only sure method for cracks or joints exposed to frost is cutting off of water at source. Pressure grouting of horizontal joints in gravity walls has not been found satisfactory. Successful patching depends largely on overcoming tendency of concrete to shrink after placing and on securing bond to parent concrete. Preshrinkage, by mixing well ahead of use and allowing to stand, has been found very effective. Methods of insuring bond include sprinkling dry cement on wetted surface just prior to patching, forcibly applying mortar to prewet surface and application of successive brush coats of thick cement grout, allowing each to dry until tacky. Latter is favored. To avoid unsightliness, mortar used must match color of concrete. Thorough curing of patch is essential. Surface to be repaired must be carefully prepared, removing all loose and decayed material and cleaning thoroughly by flushing with water. For restoration and protection of large masses of concrete, reinforced mortar applied pneumatically or ordinary concrete, placed and cured according to standard practice, may be employed. Former, in spite of cracking and occasional lack of bond, serves purpose reasonably well. Principal difference between use of concrete in ordinary construction and in repair work is the attention required in preparation of concrete to which the new is bonded. If preshrinkage is not practicable, best method of guarding against excessive shrinkage is to use concrete as dry as it can be placed. This, combined with proper preparation of surface and sufficient curing, will usually result in satisfactory joint. Several typical repair jobs are described, including repair of Ambursen type dam approx. 1200′ long and 50′ high. Author's experience has indicated that any water, even if hard, will in time rot concrete which is sufficiently porous to permit movement of water from place to place. Successful repair of upstream faces of piers which were unravelling at water-line was effected by covering with steel plates anchored to old concrete, edges being bent back into chases cut in sides of piers. Space between plate and pier was filled with grout.—*R. E. Thompson.*

Influence of the Fineness of Cement on the Permeability of Concrete. M. Mary. Compt. rend. 17me Congr. chim. ind., Paris, Sep.-Oct. '37, 264. Permeability of concrete is but slightly affected by variations in granulometric compn. of inert ingredients. For given cement content, by far the most important factor is fineness of cement. It should be remembered, also, that fineness has other effects, some favorable (greater ease of handling concrete, high final mech. strength) and others unfavorable (high thermal and hydraulic contraction). Permeability as defined in lab. is only one factor (and not the most important) of impermeability of concrete work. This quality seems to be useful especially for protecting concrete against corrosion by water.—*C. A.*

Effect of Sulfate-Containing Waters on Cement Mortar and Concrete. H. Ditz and F. Ullrich. Korrosion u. Metallschutz **14**: 154 ('38). Cement

mortars contg. 1 part portland cement to 5 parts sand (vol.) were exposed to solns. of Na_2SO_4, $MgSO_4$, $CaSO_4$, contg. 400 p.p.m. SO_3. After definite intervals, SO_3 content and alky. of solns. were detd. Sulfate was completely pptd., from which it is concluded that even water relatively low in sulfate can cause deterioration of cement, especially if latter is lean and porous. Rate of increase in alky. in soln. parallels that of disappearance of sulfate. Greater rate of pptn. of sulfate in case of $MgSO_4$ is explained by increased consumption of $Ca(OH)_2$ for pptn. of magnesia, which renders cement more porous and facilitates penetration of sulfate soln. Mortar 75 days old showed no greater rsistance than one 30 days old. Mortars that had absorbed CO_2 by prolonged storage in air or by treatment with concd. CO_2 for several days showed greater resistance. In these cases, however, larger part of sulfate was not absorbed by mortar but was pptd. in soln. as Ca Al sulfate ("cement bacillus"). This is explained by assumption that tetra-calcium aluminate, which is present in mortar low in carbonate, is transformed in presence of excess of $CaCO_3$ into less basic aluminates. In contrast to hydrolysis of tetra-calcium aluminate, hydrolysis of less basic aluminates brings alumina into soln. together with $Ca(OH)_2$, which are pptd. by sulfate present as Ca Al sulfate. Latter was identified microscopically and by analysis. Fact that cements high in Ca are easily destroyed by sulfate-contg. waters is apparently connected with greater facility of formation of the "cement bacillus," which requires Ca, in such cements. Rate of diffusion of sulfate soln. is important. In a cement stone without sand, reaction took place only at surface, and rate of sulfate pptn. was very slow.—*C. A.*

Resistance of Cement Mortar and Concrete to (Natural) Chemical Influences. HERMANN GESSNER. Schweiz. Verband Materialprüfung. Tech. Ber. No. **35:** 233 ('37). Influence of air, water and soil is discussed in detail, with classifications of Swiss water and soils. Preliminary analysis of water and soils is recommended. Injurious to cement are very soft water (total hardness under 5); water with aggressive H_2CO_3 (soft water with little aggressive H_2CO_3 is more injurious than hard water with much); soils with acid reaction (pH under 6); soils with high exchange acidity properties (Baumann-Gully rating over 20); water with more than 100–200 p.p.m. SO_3; soils with more than 2% SO_3 as detd. by HCl extn., if at same time 100–200 p.p.m. SO_3 is contained in ground water; water with Mg content of more than 100 p.p.m. MgO; soils with more than 2% MgO sol. in HCl. These values are for thin-walled cement pipe, and may be raised for heavy concrete construction if denser concrete is used accordingly. About 80 references.—*C. A.*

Simple Sand Moisture Test. STERLING S. GREEN. Eng. News-Rec. **121:** 414 (Sep. 29, '38). General practice in Los Angeles area is to limit allowable moisture content of wet sand to 1 gal. of water per cu. ft. of rodded material, equiv. to surface moisture content of 7.6%, or total moisture content of 8.2%, allowing 0.6% for absorption. Conformity to this standard may be readily checked by filling vertical-wall, flat-bottom container ⅓ full of water and adding and rodding sand until container is full. If water level reaches brim

of container before the sand, moisture content is higher than that specified.—*R. E. Thompson.*

CHEMISTRY

A Rapid Potentiometric Method for Determination of Sulfate. B. E. CHRISTENSEN, HERBERT WYMORE AND VERNON H. CHELDELIN. Ind. Eng. Chem. Anal. Ed. **10:** 413 (Aug. '38). Using shiny platinum electrode with calomel half cell, sharp break in potential was observed in titration of SO_4 with $BaCl_2$, using 25 ml. of 0.05 to 0.25*N* SO_4 soln., 25 to 60% of methanol and 1 mg. or less of persulfate. Below 0.05*N*, break was too small for analytical purposes, and above 0.25*N*, pptn. was too heavy for best results. Break in curve occurred when approx. 95% of the SO_4 had been pptd. Because of tendency for potential in alcoholic solns. to drift, e.m.f. was detd. immediately after each addn. of $BaCl_2$ and again 1 min. later, and curves plotted from e.m.f. readings after equal time intervals. Presence of sulfite, sulfide or thiosulfate completely eliminates break in potential at equivalence point. Chloride and nitrate cause no difficulty. Results are very poor in distinctly acid or basic solns.—*Selma Gottlieb.*

A Simple Method of Estimating Total Sulfates in Irrigation Water. A. N. PURI AND A. G. ASGHAR. Soil Sci. **45:** 41 ('38). Method depends on choice of indicator that will show color change in presence of Na_2CO_3 and be unaffected by slight soly. of $BaCO_3$. To the salty soln. are added 1 or 2 grams $BaCO_3$ and drop or two of 0.5% soln. of thymolphthalein in alc. Blue color is developed at once if sulfates are present; 0.1*N* HCl is then added until blue color is discharged. Soln. is boiled and titration continued. When complete, all carbonate is converted into bicarbonate but acid used cannot be taken as equiv. to half the alkali carbonate present. Soln. is filtered, washed and titrated with acid using methyl orange as indicator. Total acid used is equiv. to sulfates present. Results obtained are in agreement with those by volumetric and gravimetric methods.—*C. A.*

Tests of Mutschin and Pollak's Method of Sulfate Determination with Barium Chloride using Sodium Rhodizonate as Indicator. R. MULLER. Vom Wasser. **12:** 290 ('37). Method of Mutschin and Pollak in which sulfate is titrated with barium chloride solution using sodium rhodizonate as spot indicator is recommended for boiler water, cooling water, drinking water and river water, possessing different hardness and varying iron and manganese contents, method is rapid and accurate. Known amount of acetone (about 10% of titration liquid) is added to liquid acidified with acetic acid, pilot determination is first made using fresh indicator spots on filter paper each time. Factor for 0.2 or 0.1*N* barium chloride is found by running a blank with no sulfate, usually varies from 0.1 to 0.3 ml. of 0.2*N* barium chloride. Tables showing influence of various amounts of sodium chloride, sodium phosphate, humic acid, formaldehyde, sulfite, alone and mixed, are given, errors being between +4.9% and −3.9% even in presence of sulfite. Following is semi-micro modifi-

cation of method for waters of low sulfate content: Add to 100 ml. water 1 ml. of mixture equal parts 2*N* sodium hydroxide and sodium carbonate and heat for 5 min. Cool to 20°C. make to known volume, filter, and use 20 ml. for sulfate determination. Neutralise accurately with 0.5*N* acid using methyl orange, add 1 ml. 20% ammonium chloride, 4 ml. acetone, and 1 ml. acetic acid, finally titrate 0.1*N* barium chloride from micro burette using sodium rhodizonate as spot indicator. E. SEYB. *Ibid.* **12:** 307 ('37). Process of Mutschin and Pollak takes only 8–10 min. and is accurate to at least 4%, comparing very favorably with precipitation or benzidine processes. Acetic acid prevents precipitation of barium phosphate so that phosphate removal is unnecessary, acetone decreases solubility of barium sulfate. Relation between strength of barium chloride and amount of water must be such that after precipitation of sulfate one drop of barium chloride gives definite color with indicator.—*W. G. Carey.*

Palmitate Determination of Magnesia in Water. H. ATKINSON. Analyst **63:** 493 (Jul. '38). Drawbacks of Kitto's method (see abstract—"A Contribution to Water Analysis," J. A. W. W. A. **30:** 1737 (Oct. '38)) are that end point for total hardness determination is indefinite and that calcium is carried down with magnesium. Preferable to precipitate magnesium from boiling solution with known amount of sodium hydroxide within pH range 9.5–10, adding alkali from burette until blue color of thymolphthalein added persists in boiling solution. Filtrate is titrated with standard acid and amount of alkali added to neutral carbon dioxide free solution, less that found by back titration with acid, is equivalent to magnesium.—*W. G. Carey.*

The Titration of Alkali in Drinking Water. J. F. REITH AND APOLLONIA LOOYEN. Z. Anal. Chem. **113:** 252 ('38). The gravimetric method, weighing sodium and potassium sulfate, will give high results if percentage of potassium is high. A titration method is described. Fundamentally, the method consists of evaporating the water and heating the residue with sulfuric acid. Residue is dissolved in water and treated with excess barium hydroxide, precipitating $BaSO_4$, $Fe(OH)_3$, $Al(OH)_3$. After filtration NaOH, KOH, $Ca(OH)_2$, $Mg(OH)_2$ and $Ba(OH)_2$ is left in the filtrate. To this filtrate is added some phenolpthalein and then CO_2 is conducted through it until the clear color indicates complete formation of the bicarbonates. Solution is then boiled until red to form the carbonates. To get complete precipitation of the carbonates of the earth alkalies, a known amount of a solution of sodium carbonate is added during boiling. After cooling the filtrate is titrated with hydrochloric acid to determine the remaining alkali carbonates. Two methods are described in detail for use of this determination, one for larger amounts of sodium and one for small amounts. The preparations of the reagents and their tests are given. Errors in the methods are discussed and it is shown how they can be avoided or what corrections have to be applied.—*Max Suter.*

The Detection and Estimation of Phenols in Water. L. SCHUMANN AND H. THIEBERGER. Chem. Obzor **13:** 1 ('38). After investigation of Br water, Millou's reagent, Hinden's, Fox-Gauge, and Folin-Denis reagents authors

treat (a) a 200-cc. sample of water with 10 cc. of 50% H_2SO_4 or (b) the water with 0.2% NaOH, let it stand overnight, remove the sludge, add H_2O_2 and distil the liquid. Distillate contained 90% of the added phenols. Even without a special colorimeter it was possible to detect phenols in the range 0.1 to 3.0 mg. per liter of water. Use of H_3PO_4 instead of H_2SO_4 was not satisfactory for detns.; some of the H_3PO_4 passed into the distillate intensifying the color and giving readings which were too high. Waters contg. less than 0.1 mg. phenol per liter had to be concd.; while those waters contg. more than 3 mg. phenol per liter had to be dild. with 5 vols. of water or tested with Br water. Concn. of dil. solns. could not be done in open air but in closed vessels.—*C. A.*

Conductometric Titration of Phenol in the Presence of Fatty Acids. M. I. LAPSHIN. Zavodskaya Lab. **6:** 1405 ('37). PhOH and AcOH in mixt. in concns. to 0.001 *N* can be detd. by conductometric titration of sum of PhOH and AcOH with 0.1 *N* NaOH, AcOH with 1 *N* NH_4OH and PhOH calculated by difference. AcOH in mixt. can be detd. also by titrating with NH_4OH in presence of mixt. of equal vols. of alc. 0.1% neutral red and methylene blue as indicator. *Conductometric Titration of Phenols and Acids in the Waste Waters from Fuel Pyrolysis.* M. I. LAPSHIN and NIKOLAEVA. *Ibid.* 1455. To det. amt. of acid required for neutralization, titrate conductometrically 25–100 cc. of waste water with 1 *N* H_2SO_4 or HCl. To another 100–200-cc. sample add 5% excess H_2SO_4 and 10% $CuSO_4$ (to ppt. H_2S), reflux for 30 min. to expel volatile matter (SO_2 and CO_2) and filter. Distil filtrate with steam into 6–10 fractions of 100–200 cc., reflux each fraction for 30 min. to expel CO_2, make up to 250 cc. and proceed with conductometric titrations of aliquots (10–25 cc.) of each fraction as described above.—*C. A.*

The Determination of the Sensitivity of Certain Tests for Phenols. V. M. PLATKOVSKAYA AND S. G. VATKINA. Zh. prikl. Khim., Leningr. **10:** 202 ('37). Describes and gives results of investigation of the sensitivity of the color reactions of phenol and its derivatives with phosphomolybdic acid, phosphotungstic acid, Millon's reagent and sodium nitroprusside. Phosphomolybdic acid, in presence of ammonia was the most sensitive of these reagents for phenol. With it phenol, hydroquinone and cresol can be detected in dilution of 1:2,000,000. Adrenalin, vanillin, isoeugenol, guaiacol, cresols, α and β naphthol, and thymol produce color with phosphomolybdic acid in presence of ammonia, but not with phosphotungstic acid. Millon's reagent and sodium nitroprusside only produce colors with certain phenols; they give no color with adrenalin, vanillin, isoeugenol and guaiacol.—*W. P. R.*

The Solubility of Silica. E. J. KING. Lancet, p. 1236 (May 28, '38). The now-accepted opinion, that silica dust causes silicosis through reacting chemically upon the living tissues, attaches importance to the question of the solubility of silica in various fluids. If quartz be reduced to fine powder and then suspended in water, significant amounts of silica can be demonstrated in solution. In water and biological fluids most figures for solubility of quartz vary between 4 and 14 mg. SiO_2 per 100 cc. Difference in size of particles and presence of impurities influence degree of solubility. Substances like coal appear

to depress the solubility by adsorbing the dissolved silica; certain metals and their oxides form insoluble silicates. Minute amounts of calcium hydroxide enhance the solubility of quartz; but large amounts almost completely depress it. Bubbling CO_2 into a lime water suspension of silica restores the solubility. Metallic aluminium is a particularly efficient depressor of silica solubility and may, perhaps, be able to counteract the noxious influence of silica dust. Powdered shale may also act in a similar way. Dusts from freshly fractured minerals are more soluble than "stale" dusts. Silica is excreted in the urine; but this fact is of no diagnostic value, since food always contains some silica which readily causes variations in the urinary silica. Silicosis means more than merely fibrosis of the lungs due to the presence of silica dust; it connotes a predisposition to succumb to low-grade infection and particularly to that of tuberculosis.—*B. H.*

New Methods in Agricultural Chemical Analysis. V. Determination of Silica in Natural and Potable Waters. László Urbányi. Mezögazdasági Kutatások (Hungary) **10**: 229 ('37). Prep. a standard soln. by dissolving 2.2898 grams Na silicate and 1.5 grams NaOH to 1000 cc. Place 50 cc. of filtered water in a 100-cc. measuring flask. Place in a 2nd. flask enough of the standard silica soln. to contain 0.2–1.4 mg. SiO_2 in 50 cc. into and fill up to 50 cc. Add 2 cc. of a 25% NH_4 tungstate soln. to each flask, mix, and add 5 cc. *N* HCl, 1 cc. hydroquinone soln. (prepd. by dissolving 2.5 hydroquinone in 100 cc. of sulfuric acid soln. contg. 10 cc. concd. acid in 1 liter) and 2 cc. of a sulfite soln. (prepd. by dissolving 40 grams anhyd. Na_2SO_3 and 40 grams anhyd. $NaHSO_3$ in 400 cc. water), shake thoroughly after each addn., fill up and compare the colors after 18 hrs. If the solns. are put into a water bath at 80° for 5 min., then cooled and filled up, comparison can be made immediately. The method is suitable for waters contg. very little or no P_2O_5. The SiO_2 content of 1 liter of water is calcd. by multiplying the layer thickness of standard soln. by 20 and dividing by the layer thickness of the soln. examd.—*C. A.*

Method for Preventing the Solution of Silica by Natural Waters Stored in Glass Containers. B. A. Skopintsev and E. I. Pletnikova. Zh. prikl. Khim., Leningr. **10**: 1310 ('37). When natural waters containing 0.4–2.0 mg. of silica per liter are stored in glass vessels which give a positive reaction with iodoeosine, an increase in the quantity of silica in the water of the order of 0.15–1.6 mg. per liter is observed at the end of 1–10 days. To prevent this the sample of water should be acidified to pH 2.0.—*W. P. R.*